VAN NOSTRAND'S

ENGINEERING MAGAZINE.

VOLUME XXII.

JANUARY–JUNE.

1880.

NEW YORK;
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY STREET AND 27 WARREN STREET (UP STAIRS).

1880.

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136	II	3 from bottom	$MF=c+GF=c+k.CD; MF=\frac{D}{\cos n}$	$MF=c+GF=c+k.CD.MF=\frac{D'}{\cos n}$
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142	"	1 " top	painting	pointing
"	"	9 " "	target	largest
144	II	6 " "	secured	served
"	"	10 " bottom	contour-lines	constant-lines
149	I	4 " "	logarithms	irlogirithms
216	II	9th line for ω_1, read w_1.		
217	I	1st line for dv, read dr.		
"	"	11th line insert sin μ between wr and $[1-\cos d\gamma]$		
219	I	below the middle, in value of M, insert r between sin μ and the bracket (brace).		
219	II	in the first five lines for $d\lambda$, read $d\theta$.		
220	I	fourth line, for c, read c_0.		

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXIII.—JANUARY, 1880.—VOL. XXII.

RECENT PROGRESS IN ENGINEERING.

From the published Abstracts of the Institution of Civil Engineers.

On the Progress of Machinery.

By DANIEL KINNEAR CLARK, M. Inst. C. E.

The Progress of Public Works Engineering.

By L. F. VERNON-HARCOURT, M. Inst. C. E.

In the department of mechanical engineering, steam machinery occupies the first place in magnitude and importance; and the records of research afford evidence of the assiduity and success with which foreign engineers and philosophers have prosecuted their investigations into the generation and performance of steam as a motive power. First in order comes M. G. A. Hirn, who has, during upwards of twenty years, occupied himself with experimental inquiries into the action and behavior of steam in the steam engine, in which he has been ably assisted by his associates. He accurately appreciates the powerful and almost instantaneous operation of the walls of the steam cylinder, and their action on the steam, for every individual stroke of the piston. A portion of the steam, when cut-off for expansion, during the remainder of the stroke, is condensed as it enters the cylinder, and is, to a greater or less extent, reconverted into steam, towards the end of the expansion and during the exhaust. This action and re-action are augmented as the period of expansion is increased; and the loss of efficiency in one direction overbalances the gain of work in the other, when steam is worked expansively beyond given moderate limits.

M. Mallet gives an interesting historical summary of experimental investigation, reaching back to the year 1856, into the existence of such alternate condensation and re-evaporation of steam in the cylinder.

M. Hirn has reduced the process of test experiments on steam engines to a system remarkable for precision, and for the success with which the mechanical equivalent of heat is employed as a factor. He employs a thermo-dynamic formula, in which two series of quantities are to be equated. On the one side, there is the whole of the heat supplied to the engine, comprising the heat of the steam, taken as dry, passing into the cylinder, the heat conveyed by primed water, and the heat given up by the steam condensed in the jacket. On the other side, there is the heat converted into work, the heat lost by radiation from the jacket, and the heat delivered to the condenser. M. O. Hallauer applies this formula to the results of many trials of Woolf engines and single cylinder engines; and the valuations agree, within from $\frac{1}{2}$ to 1 per cent. of error—affording powerful evidence of the reality as well as the utility of the mechanical theory of heat.

M. Hallauer contributed the results of observations and experiments towards a solution of the question of clearance-space, in relation to the compression of exhaust steam, and its bearing on the efficiency of steam in the engine. He argued, from the evidence of indicator-diagrams, in the case of an ordinary Woolf engine, that there was a gain of 10 per cent. of efficiency by the compression of the exhaust steam, as against the absence of compression; a deduction which he was enabled subsequently to corroborate by direct proof, in the case of a Woolf engine, of which the valves were so modified as to augment the period of compression in the first cylinder, from $\frac{1}{10}$ of the stroke before alteration to $\frac{1}{4}$. The economy effected by this alteration amounted to from $3\frac{1}{2}$ to $6\frac{1}{2}$ per cent. What the radical difference of efficiency may be, due to conditions of clearance and non-clearance, is not finally settled. M. Hallauer maintains, after all, that a single-cylinder beam-engine, with four valves (Corliss fashion, in which the clearance space is minimised) and steam-jacketed, may be at least as economical as a Woolf engine or a receiver engine. The results of this experiment go to prove that for compound engines, the actual ratio of the total expansion should not exceed from 1 to 5 to 1 to 7.

M. Farcot, following up the principle of the Corliss type, constructed a direct-acting pumping engine, in which the valves of the steam-cylinder were so closely adjusted that the total clearance at each end of the cylinder was not 1 per cent. of the working capacity of the cylinder. The cylinder was jacketed with steam direct from the boiler; the fuel consumed was found, by careful trials, not to exceed 1.543 lb. of coal per indicator HP. per hour. Supposing that the water had been evaporated at the rate of 8 lbs. per lb. of coal, this consumption would correspond to 12.34 lbs. of water per indicator HP. per hour;—a performance probably unparalleled. It must be added, nevertheless, that a beam Woolf engine in regular work at Ghent, tested by M. Dwelshauvers, was proved to be capable of developing $391\frac{1}{3}$ indicator HP., with a consumption of only 14.63 lbs. of water per indicator HP. per hour, and of coal 1.94 lb. Also, a pair of compound rotative beam pumping engines for the waterworks at Lawrence, Mass., when tested for performance, consumed just 14 lbs. of water per indicator HP. These performances—one of a Corliss engine, the others of Woolf engines—may be accepted as amongst the best of their kinds, and they may be taken to show, in corroboration of M. Hallauer's conclusion, that no decided pre-eminence, in point of efficiency, can be claimed for one type of engine over the other.

It is further made manifest from the experiments of M. Hirn and his associates, that steam may be worked at least as efficiently in a single cylinder without a steam jacket, when superheated, as when worked in its ordinary state of saturation, either in a Woolf engine or in a single cylinder steam-jacketed. This is a valuable practical conclusion, which, though it has been vaguely anticipated, has not hitherto, in England, been brought to the test of direct comparison.

It is indicated by the results of experiments made by Mr. Isherwood, that a very moderate degree of super-heating suffices to secure the economy that may be effected by the substitution of superheated steam for ordinary steam in the cylinder.

Mr. Charles E. Emery reports the results of experiments with the U. S. steamers, the "Bache," the "Rush," the "Dexter," and the "Dallas," in which the performances of single cylinders and compound cylinders were compared, and the action of the steam-jacket was tested. With the "Bache," a reduction of consumption of water from 11 to 12 per cent. by the addition of the steam-jacket was effected, whilst the tendency of the evidence was to show that the compounded cylinders were more economical than the second cylinder taken alone. But the superiority of the compound system was, perhaps, more clearly put in evidence by the results of the trials with the other steamers. Comparing the "Rush," having compound steam-jacketed cylinders, with the "Dexter," having a single cylinder, felted and lagged, steam of about 80 lbs. total pressure having been employed in both cases, the most economical ratio of actual expansion in the "Rush" was 1 to $6\frac{1}{4}$, whilst in the "Dexter" it was only 1 to $3\frac{1}{2}$; and, in the "Rush," the consumption of steam was 23 per cent. less than in the "Dexter." This was the total economy, and, from the evidence with the "Bache," it may be estimated that half of this, or 12 per cent., was due to the action of the steam-jacket, and the remainder, 11 per cent., to the benefit of the division of expansive work between two cylinders. These inferences must be taken as limited to cylinders having the proportions of those on board the individual steamers, and they do not invalidate the general conclusion already drawn from the results of continental experience.

The variation of the internal resistance of steam engines with the whole work done, has been experimentally elucidated by M. Walther-Meunier, who tested a horizontal Woolf engine, with bedded cylinders, at the mills of MM. Dollfus, Mieg & Co. When the engine developed, in the cylinders, 95.5, 131. 3, and 191.3 indicator HP. successively, the power of the brake was 81.9, 86.3, and 89.1 per cent. of the indicator power respectively. It therefore appeared that the internal resistance of the engine rose slowly from 17.3 to 17.9 and 20.9 indicator HP.; and that in doubling the total indicator power the internal resistance was augmented by 3.6 indicator P. only. These data may serve to correct some erroneous assumptions with respect to the rate of augmentation of internal resistance, which, in this instance, is unexpectedly low, and which at full power did not exceed 11 per cent of the total indicator power.

The value of the mechanical equivalent of heat continues to be a subject of inquiry. M. G. A. Hirn tested it by four independent series of investigations:—of the friction of water, of the flow of water under high pressures, of the crushing of lead under a ram, and of the fall of temperature due to the expansion of air. On the evidence, taken together, M. Hirn concluded that the most nearly correct value of the equivalent was 432 Killogrammeters per calorie, or, in English measures, 787-4 foot-pounds per heat-unit. At the same time, he retained for use the value 425 kilogrammeters (or 774.70 foot-pounds), which has been adopted by most continental authors on the theory of the mechanical equivalent of heat. It may be stated, in this connection, that the Committee of the British Association for determining the value of the mechanical equivalent have reported that 772.55 foot-pounds, subject to some small correction, is the equivalent at the sea level. This value is confirmatory of the old unit, 772 foot-pounds. Nevertheless, M. Violle deduces from the results of many experiments made by him with a gyroscope revolving between the poles of an electro-magnet, the quantity, 790 foot-pounds, as the true mechanical equivalent: a value which differs little from that deduced by M. Hirn.

M. Paul Havrez endeavored to reduce to a geometrical ratio the law of the decreasing evaporative performance of the heating surface of steam boilers, as it recedes from the furnace. His deductions were based on the results of experiments by Mr. C. W. Williams and Mr. John Graham, and the more recent experiments of M. Petiet and others in France, on locomotive boilers. M. Petiet's experiments showed, that the surface of the firebox—exposed to radiated heat from the fire—evaporated per unit of surface by far the largest proportion of water, and that the efficiency of the boiler surface was rapidly reduced, advancing towards the smokebox, insomuch that the evaporation was diminished by one-half for each interval from yard to yard; that is to say, each lineal yard of tubes evaporated only half the quantity of water per hour that was evaporated by the preceding yard.

M. Paul Havrez also formulated the results of a long series of observations made by himself and his brother, with the object of determining the best proportions of boilers. He developed many novel and interesting relations between power, surface, capability, and weight of boilers of different classes, which, whether they are to be taken as final or as provisional, throw much light on some of the hitherto occult properties, with respect to efficiency, of steam boilers of various types. In the second part of his investigations, M. Havrez, led, to some extent probably, by the results of his prior investigations on the efficiency of evaporating surface, advocated a species of boiler which may be called, "united boilers" (*Chaudieres accolees*) in which he employed, to the largest possible extent, direct heating surface over a spacious furnace, with a large and extended central flue, surrounded by boilers and heaters.

The comparative merits of Lancashire boilers and French or elephant boilers, formed the subject of a course of experiments instituted by the "Societe Industrielle de Mulhouse." The results of the experiments showed a remarkable identity of performance of the two boilers, both as to evaporative performance and as to efficiency of fuel; and they tended to prove that plate heating-surface would do the same duty for evaporation, whether presented in one form or in another. The reporters concluded that, regarding economy of result, the design of the boiler was of little consequence, and that the truly important point was to provide large heat-absorbing surface in relation to the coal burned. The second part of the conclusion was in accordance with the continental taste for extensively developed heating surface, without taking into consideration the area of the firegrate.

It has been shown by the results of comparative experiments made by Prof. Thurston, that wet-tan fuel can be successfully burned under steam boilers. It was proved that, for the best action, the fuel required to be dried under the cover of firebrick ovens, the heat retained, and the combustion completed, before the gaseous products touched the surface of the boiler; and that, for the same object—the retention of the heat—the grate should be of firebrick. A boiler and furnace constructed according to these provisions, evaporated 1.74 lb. of water per lb. of wet tan; whilst in other boilers, where the same fuel was deposited on ordinary cast-iron grates, and burned in contact with the boiler surface, only 1.16 lb. of water was evaporated per lb. of wet tan.

Similar treatment has been found beneficial for the combustion and utilization of powdered fuel under steam boilers. In the experiments made by Mr. Isherwood with powdered coal, the powdered fuel was mixed with a blast of air, and burned under a brick arch turned over the firebars. The general bearing of the experimental results showed that coal, whether anthracite or bituminous, when pulverized for combustion, was decidedly less efficient for evaporation than the same fuel in lumps. But the inferiority here displayed probably resulted from depriving the boiler of the action of the radiant heat of combustion, by the interposition of the enveloping arch, which was removed when the lump coal was burned.

The value of a blast of compressed air for augmenting the evaporative power of steam boilers has been satisfactorily established by M. L, E. Bertin, who estimated that the quantity of steam consumed for compressing a supply of air to act as a blast in the chimneys of steam boilers amounted to only one-tenth of the quantity required when discharged as a blast; direct into the chimney. The power developed by the engine of the steamer "Resolve" was more than doubled by the application of the compressed air-blast to the boilers, whilst the power required for the generation of the blast did not exceed 5 per cent. of the power of the engine.

In America, a spiral exhaust-nozzle has been introduced by Mr. Thomas Shaw, by the use of which the noise of steam blowing-off at the safety-valves of locotives and steam vessels is effectually quelled.

The causes of corrosion and incrustation of steam boilers have been perseveringly investigated by French engineers. M. Hétet explains that the deposits which take place in steam boilers, worked with surface condensers, consist of iron oxide and acid fats, forming ferruginous soaps containing 50 per cent of iron, and that the iron is obtained by internal corrosion of the boiler. He employed a chalk mixture to neutralize the acid, and to arrested the corrosion of the boiler and thc formation of deposits there. M. Allaire contends for the substitution of refined neutral oils, which are chemically harmless, and are totally consumed in the cylinder without suffering decomposition or generating deposits. M. Stapfer also proposes the use of mineral or neutral oils for lubricating, although he notices that a stiff gum-like substance may be formed, analagous to caoutchouc, which adheres to the piston-rod.

M. Audenet suggests that a species of

trap should be placed at the entrance from the exhaust pipe to the condenser, for the interception of greasy impurities. He estimates, from the results of sobservations made on the surface-condensers of the "Dives," that the quantity of heat which passed through tube-surfaces when new, amounted to 500 units per square foot per hour per degree Fahr. difference of temperature. But he recognises that this value must be diminished by dedosits of fatty matter, and he alludes to the consequent loss of vacuum in transatlantic steamers fitted with surface-condensers, amounting to from 1·20 to 2·40

For the prevention of incrustation, zinc and talc have each been used in steam boilers. The effective action in each case is mechanical in its nature. With zinc, according to M. Lesueur, a decomposition of water takes place, by which the zinc is oxidised, whilst free hydrogen gas is discharged from the surface of the iron plates of the boiler, and baffles, in a greater or less degree, the deposition of scale on the surface. It does not appear that much is to be hoped for from the zinc process; but the talc process promises better. Pulverized talc has been employed successfully in locomotive boilers on the Paris and Lyons Railway, and, whilst it prevents incrustation, it has also the effect of reducing the friction of the pistons and the piston-rods. Its action appears to be purely mechanical; in virtue of its scaly structure, it presents a great extent of surface, offering many points of attachment for the salts of incrustation.

MM. Beranger and Stingl have arranged a process of preliminary purification of the feed-water of boilers, in which the inorganic elements of impurity are precipitated by chemical treatment, and the water is decanted and filtered prior to its being delivered to the boiler.

The theory of furnace chimneys has been discussed by continental writers. Whilst Signor P. Guzzi assumes that the draught increases with the temperature at all temperatures, M. Cornut, who is probably in the right, maintains that the draught, though it increases at first with the temperature, diminishes with the higher temperature, and that it reaches a maximum when the temperature amounts to 560° Fahr., taking the external air at 50° Fahr. Mr. Robert Briggs gives a useful formula for the sectional area of chimneys for steam-boilers.

In the practice of locomotives, attention continues to be directed to the development of full-power engines. Herr Steinberg in conjunction with Herr Schau, designed and employed an eight-wheeled coupled engine for the traffic of the Poto-Tiflis Railway. The wheel-base was limited to 10 feet 8 inches, when employing wheels of only one meter in diameter. Radial axles were not employed, but the leading and the trailing axles were simply free to move laterally.

In a posthumous memoir, by M. Le Chatelier he recommends the employment of two engines coupled together for mountain traffic, but he omits to point out how they should be connected, so that they may not baffle each other. For the satisfactory solution of the problem of full-power enginea, flexibility of base, combined with radial axles mvst be recognized as necessary elements. The principle of the double bogie, already already worked out in England by Mr. R. F. Fairlie, has been applied by M. Rarchaert in a locomotive, which is placed on two four-wheeled bogies. The wheels of the bogies are coupled, and the bogies are also coupled together by a central coupling-rod under the boiler, to which the power of a single pair of cylinkers is communiceted through a transverse crank-shaft. Compared with an ordinary six-coupled-wheel engine, the relatively slight wear of the wheel flanges attested the greater freedom of the Rarchaert engine on the rails, It also employs the whole of the weight for adhesion, with one pair of steam-cylinders

The central-rail locomotive for mountain traffic, as described by M. Desbriére, has been gradually improved ; although it remains a question to be settled by experience, whether two cylinders or four cylinders should be employed. In tqe engines of this kind, constructed for the Cantagallo Railway, Brazil, by the introduction of a few obvious and simple modifications, the breakage of the machinery, frequent in engines of an earlier class, have disappeared; whilst in other engines, for New Zealand, the dispersion of oil from the interior machinery upon the surfaces of the central rail, has been entirely prevented by the application of a shield.

To diminish the wear of the flanges of the leading wheels of locomotives tablets of grease, or of felt saturated with oil, have bean employed in Bavaria with success; applied so as to lubricate the flanges. It has been observed that the duration of the flanges is increased 50 per cent. by the lubrication.

That the link motion of Stephenson is not likely to be superceded for the valve gear of locomotives, has been proved by the results of a long series of experiments conducted by Professor Bauschinger, on a Bavarian Railway. Testing the comparative merits of the link motion and Meyer's valve-gear, the water consumed per HP. per hour was 37·4 lbs., with Mcyer's gear, whilst with the link-motion it did not excaed $30\frac{1}{2}$ lbs. The consumption of fuel were proportionally different. The comparative economy effected by the use of the link motion is ascribed—and, with much probability, justly ascribed—to the compression of exhaust steam, which takes place in cylinders fitted with that motion,

Continental railway engineers are taking active steps for preserving the boilers of locomotives. On the Thuringian lines of railway, the feed water, derived from the limestone and gypsum, rocks, has for some time been purified by treatment with chloride of barium and caustic lime, in settling tanks. An experimental trial of Herr A. Feldbacher's invention for preventing incrustation by lining the boiler with sheet copper, was made in a shunting engine at the Vienna terminus. The result of the trial showed that the system was completely successful in preserving the plates from incrustation and from corrosion.

Steam power has been substituted for the power of horses on light railways, with great economical advantage. At the iron works at Decazeville the cost has been reduced from 2·41*d.* per ton conveyed per mile by horses, to 1·56*d.* by locomotives. Similarly, in the coal mines at Doman, in Hungary, the cost has been reduced from 2*d.* per ton of coal drawn by horses, to a little over 1*d.* per ton drawn by locomotives.

The introduction of compound cylinders for locomotives, by M. Mallet, on the Bayonne and Biaritz Railway, is a new departure in the improvement of locomotives, which lend themselves readily to the compounding of the cylinders. It does not appear from the results of performance hitherto made public, that there is any distinctive economy of consumption in the compounded locomotives. The absence of economy is the natural consequence of the absence of steam-jackets or superheating apparatus. Meantime, M. Mallett has demonstrated the feasibility of the compound system in locomotives; economy will, no doubt, follow. In the same paper, M. Mallet summarizes the investigations of various experimentalists on the action and behavior of steam in the cylinders of locomotives.

According to an exhaustive report on the system of warming railway carriages in England and on the Continent, there is great diversity of opinion as to what constitutes the best system; though it is acknowledged that, in England, the common footwarmer is by general consent accepted as satisfactory, whilst it is the least expensive system. The reporter agrees in this conclusion.

The results of test-trials of turbine water-wheels on the continent and in America, appear to establish the superiority of the inward flow-kinds of turbine, originally designed by Professor James Thomson. Of these, the best recorded perfoemance is that of a Swain turbine, 72 inches in diameter, having a maximum gate of 13 inches, at Boot Cotton Mill, U. S. The turbine was tested by Mr. J. B. Francis. In the Swain turbine, the discharge is inward and downward. The receiving edges of the floats of the wheel are vertical, opposite the guide-blades, and the lower portions of the edges are bent into the form of a quadrant. Each float thus forms, with the surface of the adjoining float, an outlet which combines an inward and downward discharge. A maximum efficiency of 84 per cent. was attained with a 12-inch gate; with a 9-inch gate an efficiency of 83 per cent. was attained; at half-gate, 78 per cent.; and at quarter-gate, 61 per cent. These performances, taken tgether, are unrivalled by any other performance recorded in the abstracts. Girard turbines — tangential wheels specially suited for very high falls—are employed at the works of the St. Gothard tunnel. They have a diameter of 7 feet $10\frac{1}{2}$ inches, and they make

160 turns per minute, with a maximum charge of water of 67 gallons per second. They are remarkable for the unprecedented head—279 feet—under which they are worked.

THE PROGRESS OF PUBLIC WORKS ENGINEERING.

The first place must be assigned to the St. Louis Bridge over the Mississippi, designed by Mr. James Eads, M. Inst. C. E. This bridge, which carries a roadway above and a railway below, on girders formed of two arched steel tubes braced together, has two spans of 502 feet and a center span of 520 feet. It supplies a proof that, by the introduction of steel instead of iron, the weight of the superstructure of a bridge may be considerably diminished, its cost reduced, and large spans adopted even for carrying two roadways. The success of the undertaking furnishes a forcible argument in favor of removing the restrictions placed hitherto upon the employment of steel in this country. The method of erecting the bridge without scaffolding is worthy of notice. The girders were built out from the piers for a quarter of their length, and being fastened to the pier at the springing bore their own weight like a bracket, and the remaining portion was added by supporting their ends by iron ties from temporary erections on the piers. The principal object in forming such large spans was to diminish the number of piers, as the foundations were difficult and costly. The foundations for the piers of this bridge have been described in a paper by Mr. Francis Fox, M. Inst. C. E. At the time of their execution, the depth of the bottom of the east pier, 102 feet below water, was the greatest on record. Other instances of pneumatic foundations are given in the Abstracts, amongst which may be mentioned the résumé of various kinds of foundations for large bridges by Herr Funk, in which reference is made to the East River Bridge caisson, and to a bridge which is being built over the Lymfjord in North Jutland on iron caisson foundations reaching a depth of 118 feet below low water. The recent paper "On Foundations," by Professor Gaudard, renders further reference to these and other instances unnecessary.

The Kentucky river bridge is worthy of notice for the manner in which the center truss, 275 feet above low water and 375 feet span, was erected without scaffolding. Temporary piers were erected between the abutments and piers; the girders were then built out from the rock abutments on each side, being supported by the anchorage bolts till they reached the temporary piers. The building of the girders was next continued till the permanent piers and eventually the center of the centre span was reached, and the two portions united. The account of the Dwina bridge at Riga shows how large foundations have been put in under peculiar difficulties, exposed to a rapid stream and the breaking up of ice. The Moerdijk bridge over the Hollandsche Diep, whose foundations have been described in a paper by Sir J. G. N. Alleyne, Bart., M. Inst., C. E., is chiefly remarkable for its length, as the estuary where it crosses is 2,840 yards wide. The Marseilles swing bridge is an instance of a large and heavy bridge being moved round with perfect ease in three minutes by one man with the aid of hydraulic machinery.

Light railways and narrow-gauge railways have been introduced more extensively abroad than in this country, owing to the population being more scattered, to the absence of good roads, and to the importance of obtaining means of communication at the least possible cost. Also, in many mountainous districts steep gradients and sharp curves cannot be avoided in laying out railways, and the gauge and locomotives have to be made subservient to these requirements.

Amongst the railways where the standard gauge is adhered to the light railways in Hungary must be mentioned, as they represent the class of railway contemplated in the clause in the Regulation of Railways Act, 1868, authorizing the construction of light railways in this country, of which there are only three actually open for traffic, though others have been authorized, and one or more in course of construction. The two light railways in Hungary are each about twenty-nine miles long, and pass through a fertile district having bad roads. They are laid with rails weighing fifty-one pounds per yard, and cost a little over £4,000 per mile; the greater portion of the land was given for the railway; and the country being fairly level, the earthwork was small, the gradients are slight, and the curves are few, the sharpest having a radius of twenty chains. These afford a good instance of railways made economically, at the request and with the assistance of the landowners, for the purpose of obtaining the necessary means of communication. Lines like these are, in the author's opinion, the proper ones for supplying deficient railway accommodation in parts of England where the traffic would be unlikely to render lines constructed in the ordinary manner remunerative, and the hearty support of the landowners is an essential element in such undertakings. In Sweden this class of railway appears to have been extensively and successfully adopted, 1,730 miles being open for traffic or in course of construction.

The Uetli railway is a totally different type of line. It was made for the purpose of reaching the summit of the Uetli mountains, with steep inclines and sharp curves; the worst gradient is one in fourteen, and the sharpest curve 6.7 chains radius; the rails weigh sixty pounds per yard. It rises 1,310 feet in its length of 5.7 miles, and cost £11,100 per mile. It is worked by six-wheeled coupled engines, proving that inclines of one in fourteen can be safely ascended by locomotives. The train, composed of three carriages, performs the ascent in half an hour, and in its descent is kept under perfect control by air brakes.

The meter gauge has been adopted for several railways: for instance, on the line of Ergastiria in Greece, of Mokta-el-Hadid in Algeria, on three lines in Switzerland, and in France, Sardinia, and Austria. Bessemer steel rails were adopted in some of the above instances weighing from forty one to fifty-seven pounds per yard; the radius of the sharpest curve is about three chains, and the maximum gradient one in twenty-eight. In India this gauge has been adopted for all the narrow-gauge lines, of which there are 2,700 miles projected, and about one-third of these were completed in 1874. From a valuable collection of statistics about narrow-gauge railways, by M. Morandiere, it appears that the number of these lines has increased enormously of late years; the total number of miles opened for traffic in 1874 being 5,040, and 10,812 miles being under construction. The United States head the list with 2,040 miles open, and 7,552 in construction. India comes next, and then Canada, Australia, New Zealand, and Russia, whilst Great Britain is near the bottom of the list with twenty-six miles, being less than Java, which possesses thirty-four miles. There are twenty varieties of gauge on these lines, lying between one foot six inches and four feet; but next to the meter gauge, a gauge of three feet six inches appears the most common, having been adopted in Norway, Canada, the Cape, and on some American lines. It is natural that narrow-gauge lines have been little developed in England, France, Germany, and other continental countries, as the objections to the break of gauge in India, urged by several speakers in the discussion on Mr. Thornton's Paper on State Railways in India, apply with much greater force to the principal countries of Europe. An alteration in gauge can only be expedient in cases where it would be impossible to raise sufficient capital for constructing an ordinary-gauge line, and the choice lies between a narrow-gauge line and none at all. An instance of this occurred in the Grand Duchy of Oldenburg, where, in order to connect Ocholt and Westersede, each situated on railways of ordinary gauge, it was necessary, owing to the poverty of the country and the scarcity of the population, to construct the cheapest possible narrow-gauge line. This railway, which is nearly $4\frac{1}{2}$ miles long, was constructed in 1876 in less than six months, at a cost, including rolling-stock, of £10,450; it was laid to a $\frac{3}{4}$-meter gauge, with Bessemer steel rails weighing twenty-five pounds per yard. Four trains run each way daily at the rate of about $13\frac{1}{2}$ miles an hour; the fuel used is peat, and the daily expenses amount to only £1 9s. The Eibenthal mineral line furnishes an instance of a narow-gauge railway economically constructed through a hilly country. The gauge is two feet six inches; curves of one chain radius have been adopted, and when the line, at present worked by horses, is made available for locomotives, the total cost, including rolling-stock, will amount to only £1,857 per mile.

Riggenbach's rack system for sur-mounting steep gradients, first adopted on the Rigi railway, has been extended to seven other railways. In the Ostermundingen railway the central rack-rail is only laid for the rising portion of the line. The locomotive works like an ordinary one along the level, and when it reaches the ascent of one in ten, the machinery is put in gear with the rack. A similar arrangement has been adopted on the Wasseralfingen railway, which has a gradient of one in 13, for about half a mile in length. Herr Wetli has invented a system for drawing trains up steep inclines by the help of a drum, placed under the locomotive and connected with the driving-wheel, with spiral threads, running in opposite directions from the center to the sides of the drum, which wind along a pair of guide rails placed in a Λ form at short distances apart. Herr Brockmann considers this system superior to that of the Fell railway, and also to that of the Rigi railway, in which the teeth of the central rack cannot be made strong enough to bear heavy traffic. Endless wire ropes are used for drawing the tram-cars up some steep streets in San Francisco, the connection between the rope and the car being so contrived that the rope is entirely below the road level, and causes no obstruction whatever to the ordinary street traffic.

Tramways along streets and public roads are being gradually extended. A concession was granted in 1873 for laying down sixty-six miles of tramways in Paris; and a steam tramway along the high road from Cassel to Wilhelmshöhe has been recently opened. Compressed air was tried first on this latter tramway, but proving a failure, Messrs. Merryweather's steam engines were substituted, which can draw two fully loaded cars up the gradient of 1 in 16.6. In Paris, Messrs. Merryweather's locomotive, the fireless or hot-water locomotive of M. Francq, and M. Mékarski's compressed-air engine, have been tried. It is stated that the use of the steam locomotive in Paris has not produced a saving of expense. This is contrary to the experience gained with similar engines at Copenhagen, where a saving of 40 per cent. was effected in the cost of working; with locomotives on the light Firmy railway, where a saving of one-third was made, and with Baldwin's steam car in America, where 18 per cent. was saved. The employment of fifteen fireless or thermo-specific engines on the New Orleans tramway effected an economy of 50 per cent. over the traction by horses. The performance of M. Francq's engine is to be further tested on the Paris tramways. M. Mékarski reckons that traction by his engine costs the same as with steam locomotives, and effects a saving of 25 per cent., or, according to his latest calculations, 40 per cent., on the total cost of traction with horses. A tramway in the surburb of Brussels is worked by a steam locomotive, entirely encased, to avoid frightening horses. It draws a weight of 2½ tons up an incline of 1 in 50, at the rate of 7½ miles an hour. Special compact locomotives, similarly disguised, have been used on tramways at Belfast and New Orleans; and locomotives have been introduced on some tramways in Italy.

A steam carriage, made entirely of steel, and weighing about four tons, for carrying twelve passengers, or drawing goods along an ordinary road, has been designed by M. Bollée. It accomplished a journey of 150 miles in eighteen hours. It can easily travel twelve miles an hour on the level, and 5½ miles up an incline of 1 in 20, drawing a weight of four tons. It is easily steered through a town, and is said not to frighten horses, owing to the little noise it makes. M. Belpaire has designed a steamcarriage furnishing accommodation for fifty passengers. It can travel at the rate of forty-five miles per hour on the level, and twenty-five miles per hour up an incline of 1 in 62. The working expenses are reckoned at 1*d.* per mile run.

A description of the Heberlien continuous brake is given by M. Massauge. It was applied in 1874 to a train running between Brussels and Luxembourg, and acts on the principle of stopping a train by force accumulated during its motion. A new counter-pressure and vacuum brake, an improvement on the Le Chatelier system, is also described. These are the only continuous brakes to which reference is made in the Abstracts, but it is natural that less attention should have been paid to this subject abroad than in England, as—except on a few of the principal through routes—the speed of the trains abroad is much less than in this country.

A new steam pile-driving machine, invented by Herr Lewicki, was used on the river Dwina regulation works, by which, on an average, fifty piles were driven per day. From a series of experiments it was found that the steam pile engine did twenty-eight times as much work as an ordinary pile engine worked by four men; and the cost is estimated at 8¼*d.* per pile for the steam ram, and 4*s.* 6½*d.* for an ordinary ram. The peculiarity of the pile-driving apparatus described by Herr Weber is that a single steam engine controls several rams. The apparatus consists of an engine, of any kind with which driving bands can be used, the power distributor, and the ropes or chains for lifting the monkey. This invention was used on the Elbe at Dresden, for driving the piles of a quay wall, 541 yards long, where three pile-drivers were used. The work of driving about two thousand one hundred piles into a bed of rough gravel and stones, to a depth of from 3½ to 7 feet, occupied thirty-two days. If ordinary hand pile-drivers had been used, the cost would have been increased by about 14 per cent., and the work would have lasted at least fifty-five days.

The powder-ram, invented by Mr. Shaw in the United States, and improved by Herr Riedinger, was used in constructing a bridge over the Elbe at Dresden. A cartridge of gunpowder thrown into a mortar, resting on the pile to be driven, is exploded by the fall of the ram, which drops into the mortar, and the gases formed in the explosion both drive the pile down and shoot up the ram to its original position. This ram is said to be rapid, efficient, and cheap. About twenty-seven piles could be driven per day, and the cost per pile, driven 7.2 feet, is reckoned at 8*s.* 6*d.* The great apparent difference in rapidity and cost between the results obtained with the powder-ram on the Elbe and the steam pile driver on the Dwina must be partially due to the difference in the bed of the two rivers —the bed of the Elbe consisting of rough gravel and stones, and a sort of quicksand overlying sand mixed with clay forming the Dwina river bed. Pile-driving in sand by the injection of water, from pipes carried down the sides of the piles, has proved very expeditious and efficient at the new harbor works at Calais, doing the work in about an eighth of the time occupied by the ordinary methods.

Though some important sewerage works, such as the drainage of Berlin, of Rome, and of Düsseldorf, are described in the Abstracts, there is no record of the introduction of any new system for dealing with sewage. The sewage of Berlin is to be disposed of by irrigation, and at Rome and Dusseldorf the sewage is discharged into the Tiber and the Rhine. At Paris considerable pollution of the Seine occurs from the influx of the sewage; the sluggish nature of the stream favors the deposit of the solid refuse matter, estimated at 130,000 tons annually, and dredging has to be resorted to for keeping open the mouths of the sewers. The Seine Pollution Commissioners unanimously rejected all chemical methods of purification, and expressed their conviction, from the results of irrigation tried on the plains of Gennevilliers, that irrigation was the proper method of disposing of the Paris sewage. These sandy plains have an area of 800 acres. The effluent water after irrigation contains only 1 part or 2 parts of nitrogen, having previously contained 44 parts. The improvement of the irrigated land in productiveness is very manifest. Vegetables, fruit-trees, and flowers grow well on the land, and the gross yield per acre is from £24 to £48 in the open fields, and in some well sheltered and cultivated parts it has reached £112. At Dantzic sewage irrigation experiments, commenced in 1871, have proved satisfactory both from a sanitary and agricultural point of view.

Hydraulic engineering occupies a prominent place in the Abstracts, and many important works, such as breakwaters, harbor improvements, reclamation works, reservoir dams, the regulation of rivers, the irrigation of dry or barren plains, and water-works for towns, are described; but most of the articles are valuable rather as records of successful applications, modifications, or extensions of well-known principles, than as embodying any special novelties of design. The dam across the valley of the Gileppe is a notable instance of a masonry dam made exceptionally strong for retaining a volume of water amounting, when the reservoir above it is full, to 16,010,000 cubic yards, and covering an area of 198 acres. It is 154 feet high, 216 feet broad at the base, and 49¼ feet broad and 771 feet long at the top. The Furens masonry dam, across the valley of Enfer, having a section which approximately coincides with the theoretical law as given in the article on the Gileppe dam, is 170 feet high, 110 feet broad at the base, and 9.8 feet broad at the top. These dams, however, whilst claiming notice on account of their size, are not quite without precedent, as the Alicante dam, nearly three centuries old, is 134½ feet high.

In supplying the Aix (provence) district with the water from the river Verdon, it was necessary to convey the water across the valley of St. Paul. As the construction of an aqueduct would have caused considerable delay, and involved a large expenditure, the novel expedient of carrying the water across the valley in an inverted siphon was adopted. Two wrought-iron pipes, 5 feet 9 inches in diameter, form the siphons; they are laid horizontally across the bottom of the valley for a length of 322 feet, and rise on each side of the valley, with inclinations of 1 in 2.44 and 1 in 2.7 for lengths of 251 and 276 feet respectively.

The drainage of Lake Fucino, rendered advisable from the absence of any natural outlet for the rain falling within its basin, is chiefly interesting for having been contemplated by Julius Cæsar, attempted by some of the Roman emperors, and again in the middle ages by Frederick II., and at length accomplished within the last ten years. The water is conveyed into the river Liris through an egg-shaped tunnel (19 feet by 13 feet) 6,887 yards long. In the construction of this tunnel twenty-eight shafts and two inclined galleries were made. The lands bordering on the lake, which were flooded in wet weather, and converted into unwholesome marshes in dry weather, have been greatly improved in value, and 35,000 acres have been reclaimed by lowering the waters of the lake.

The difficult task of keeping open a navigation channel at the mouth of the Mississippi has been successfully accomplished, by contracting the South Pass into a uniform channel, 850 feet wide, by wooden jetties on each side, the channel being for a time still further confined at the sea end by wing dams to increase the scour; and mattress sills have been sunk across the two other principal channels to divert more water into the South Pass. The navigation channel has already enlarged, and the original depth of 8 feet has been increased to 20 feet. It is anticipated that the scouring action will be still more effectual when the jetties are completed, and that, if a bar should tend to form at the sea end of the channel, an effectual remedy could be provided by the gradual extension of the jetties seaward at a moderate cost.

Though movable dams or weirs across rivers cannot be regarded as new inventions, having been for many years extensively employed on French rivers, and an instance being recorded of the erection of a movable dam in America in 1818, where they are now being gradually introduced, they are little known except in the simplest form in this country. M. Boule has designed a new form of dam, which he considers specially suitable for dams higher than 12 to 14 feet, the limits of the Poirée spar or needle system and of the turning floodgate of M. Chanoine. In M. Boule's design the shuttles are placed in tiers, between slight wrought-iron upright supports, 3½ feet apart, carrying the foot-path, so that the shuttles can be readily removed and replaced. In America shuttles hinged at the bottom, maintained in their places by props, and falling down flat on the apron of the weir when the props are removed, have been introduced. A somewhat similar principle has been adopted for some movable dams on the weirs Vizézi and Moingt; but in these dams the central pile supporting the shuttle is propped up, and the shuttles are composed of several boards laid horizontally, which can be removed successively, if the instantaneous removal of the whole dam, by releasing the prop supporting the central pile, is not necessary. A sluice-gate formed of narrow horizontal-jointed boards like a shutter, and winding up round a roller, has been put up at the weir of Notre-Dame-de-la-Garenne, on the river Seine. In the Mérienne dam on the Charente, by omitting the upper portion of the lower cheeks of the grooves in which the shuttles slide, the shuttles, when lifted to a certain height, being hinged to the racks, rise by the pressure of the flood-waters towards a horizontal position, sinking again into their places when the flood has abated. A self-acting shutter for maintaining a constant head is described by Signor Nicorini.

French engineers have devoted considerable attention to the flow of rivers, and several valuable papers have been written on this subject, especially with reference to the Seine. The floods of the Po have also been carefully observed and recorded during the present century, furnishing important evidence of a gradual rise in the flood level. By a careful study of the Seine basin, and the flow of its tributaries, and by means of extensive daily rainfall observations, the late M. Belgrand has been able to predict at the beginning of the summer a drought in the autumn, and to forecast the rise of the Seine in flood time at Paris so as to give timely warning to the inhabitants along its banks. On the 14th March, 1876, M. Belgrand announced that the Seine, which was in flood, would reach a definite maximum height at Paris on the 17th of that month; and his prediction was fulfilled within half an inch. Floods of the tributaries of the Seine have been similarly predicted, and in the opinion of M. Belgrand the same system might be applied with success to many other rivers. The Author considers that a similar study of the flow of rivers in this country would furnish valuable information, at a time when the prevention of summer floods is becoming, in many districts, a matter of pressing importance.

The Ar-men lighthouse is being constructed on a reef of rocks near the Isle of Sein. The low level of the Ar-men rock on which the lighthouse rests, the rapid run of tide across the reef, and the exposure to the wind, rendered the foundations peculiarly difficult to put in; and the work was only accomplished by the energy of the native fisherman, who undertook the hazardous task of drilling the holes in the rock for receiving the iron dowels, to which the foundation courses of masonry were subsequently secured.

In this brief notice the Author has merely touched upon a few out of the many descriptions relating to public works abroad which have appeared in the Abstracts; but he trusts that those he has selected will suffice to show, that much may be learnt from a study of the practice and progress of public works engineering abroad, and in particular from the Americans in the matter of steel bridge construction, and from the French with reference to rivers.

Coal in China.—An attempt is contemplated to work coal mines in the neighborhood of Ching-men-Chow, not far from Ichang. Boring operations were commenced late last autumn. The coal-producing country appears to cover an extent of seventy-five square English miles, fifteen long by five broad. There are ten layers of coal, one above the other. The bed in Watzukow is estimated to be 500 English acres in extent; that at San-li-Kang to be one-fourth of its size. It is supposed that 1,200,000 tons of coal can be raised from Watzukow, and 800,000 from San-li-Kang, at the rate of 40,000 tons a year. The supply thus would last at least forty years. It is highly probable that further explorations will bring to light fresh beds, as these discoveries are the result of merely the first investigations. It should be mentioned that a few mines have been opened by the people living in the district, but they have not penetrated to the level of the best coal or largest seams. The bed at Wotzukow is 100 feet below the surface. The coal is just the same as the best American anthracite which is brought to China. Specimens of all the native and foreign coal procurable in China have been analyzed together and the new coal has shown itself superior to all for smelting purposes. The province of Hupei possesses several mines containing iron of excellent quality. If these are worked in connection with the coal mines large profits should be obtained, and if the example be followed in other provinces a source of wealth to the whole country will be opened up.

EFFECTIVE VENTILATION.

By H. C. STEVENS.

From "The Building News."

A house dwelling should afford us shelter from wind and rain, and while enabling us to obtain a comfortable temperature, should not deprive us of pure air for breathing. The ordinary house dwelling certainly provides us with shelter, but the requisite temperature and the pure air are obtained wastefully and with life-lowering insufficiency. The warming and ventilation of buildings is an intrinsically difficult subject, requiring unusual thoroughness and comprehensiveness in experiment. An illustration of the danger proceeding from the neglect of strict experimental investigation was afforded by the very general misconception with regard to the work performed by cowls in ventilation, which prevailed, until the president of this section (Captain Douglas Galton), with his colleagues upon the Ventilation Committee, published the results of their experiments at Kew. It is to be hoped that the very great public benefit conferred by that investigation will not be limited to the dispersion of the unfounded pretensions of the cowl supporters, but that it will inspire an attitude of sceptical inquiry towards ventilating appliances in general. Perhaps, also, a lack of precision in language has contributed to obstruct our progress. I may mention the word "draught" as an instance of this. In the popular sense of the word, a draught means a stream of air of highly uncomfortable and dangerous quality, and generally we find the effect of movement in the air and the impression derived from its quality are confounded one with the other! Air perfectly at rest—stagnant air—though its quality may be good, is not agreeable to us, and perhaps not healthy. Mere movement in good air is agreeable and stimulating; fanning is so. Thus, in ventilation, a current or draught is distinctly an object to be attained, but of course the draught must consist of pure air, agreeable in temperature and in its other qualities. I will define the ventilation of houses as the maintenance of the atmosphere of a dwelling in that condition of purity, temperature, movement, and moisture, which is found to be most agreeable to its inhabitants, and most conducive to their health and vigor. I think this definition is sound, although it goes beyond the limited sense in which the word is usually employed. The many modes of ventilating at present practised may be classified as belonging to three fairly distinct principles. 1st. We have ventilation by the natural or spontaneous method, or, as I prefer to call it, ventilation by the *exterior wind agency*, 2nd. We have ventilation by the operation of gravity obtained in ventilation by *heat agency*. 3rd. We have ventilation by mechanical appliances, as blowers, fans, or pumps, which may be described as *mechanical agency*.

Ventilation, dependent upon the *Exterior Wind agency* principle, is the form commonly employed for the introduction of fresh air into house dwellings in this country. The appliances for it are various in character. Among them are very numerous contrivances applied to holes in walls of buildings. To this principle also belongs the introduction of fresh air by tubes which convey it into the interior of dwellings in a manner to cause the least annoyance and discomfort. Tubes for extracting air open at the top, or surmounted by a cowl, whether used in conjunction with some mode for admitting exterior air or not, must also be placed in this class. In many of these contrivances the action claimed for them as proceeding by their operation, from difference in temperature between interior and exterior air, does take effect to some extent, but such action is altogether inconsiderable when compared with the influence exerted by the exterior wind currents to which the tubes are exposed. I would ask your earnest consideration as to the value and expediency of relying at all upon the force of natural wind currents for a supply of air for breathing purposes, and it would be a great step in advance to acquire clear views upon the merit of this form of ventilation. A leading cowl manufacturer in his prospectus says that the wind has an average velocity of ten miles an hour in this country—it is easy to calculate an average, but to be of use for ventilation that average speed should have a reasonably enduring continuance, it should represent a normal condition of the wind force—the wind in this country actually varies from about 1 to 30 miles per hour, however seldom such extremes may be touched. I live in the midst of trees and note the play of their foliage. I have ventilators based upon this exterior wind agency principle in some of my rooms, and I have carefully watched their action; both the foliage of the trees and the action of the ventilators attest the incessant and wide variation of the force exerted on them; further than this these appliances only deliver air when the wind is blowing on their side of the house, then those on the windward side deliver air rapidly, while from those on the leeward side no current is perceptible. It is true that when a fire is burning air will enter through them to compensate for that driven out by the fire currents; but the quantity and force will depend mainly upon the exterior wind currents. At one time air enters sufficient to replace that driven out by the fire currents; at another, irrespective of the action of the fire, the wind rushes in in an unwelcome torrent. In summer when there is in the temperature of the interior and the exterior of our dwellings but little difference, ventilation by appliances, really dependent upon "exterior wind agency," are often quite inoperative. The air is then frequently so still that a candle flame will suffer hardly any apparent deflection, even when passed through an open window, and at such times no current can be detected from tubes or other openings communicating with the external air. It is, however, precisely at such times that the need for the introduction of fresh air at a reliable rate is most felt. On the other hand, when the wind is driven through every chink and cranny of our houses, the air-tubes on this principle deliver a superfluous and unbearable addition to it. For the ventilation of sewers, cellars, and for what I can best describe as *air-cleansing work*, the fitful, but from time to time powerful and thorough sweeping obtained from the full force of an exterior wind current, is most valuable; but our respiratory process is regular and uniform, and something like a corresponding uniformity in the quantity and quality of the air supplied to our dwellings is required by us. If this be conceded, I submit that the admission of the force of wind currents is pernicious, and must frustrate the attainment of reliable and uniform ventilation.

Ventilation on the second principle, by *Heat Agency*, is a great improvement on that obtained by exterior wind agency; but if applied to extracting air by chimney draughts, the admission of air is usually allowed to depend upon appliances largely controlled by external wind currents. In summer the plan of propelling air by heat ventilation cannot well be carried out, and the stoves devised for it usually operate at that season of the year upon the external wind agency principle with its inaction during the hot calms of summer, and excessive action when the natural leakage of our houses introduces air enough.

It is by the employment of the third principle, that of *Mechanical Agency*, that we can alone become masters of the situation—able to introduce air at any required rate, and, at the same time, do very much towards raising its life-sustaining value. By the use of fans, blowers or pumps, the quantity of air admitted is placed under easy and immediate control, and its condition can be modified so as to bring it to a near approximation with any desired standard. To furnish power for blowing or pumping air into large buildings is simple enough; but its application to the needs of private dwellings in a manner sufficiently simple, automatic, and inexpensive, is surrounded with considerable difficulty. The ordinary means for the application of power appeared incapable of furnishing a flow of energy in a form sufficiently attenuated for a machine required to do work as undeviating, and as constant as the process of respiration within ourselves. The descent of heavy weights, governed by clock work movement, affords an arrangement by which a considerable amount of energy can be stored and liberated with uniformity at any desired rate.

A descending weight of one ton might run in a shaft by the side of a house from the top to the bottom, or from the basement downwards in a tube to any convenient depth, or by combining the two, a vertical fall of many feet would be obtained. The weight could be raised by multiplying pullies by hand power, or by any form of engine, steam, wind, hot-air or gas; but by using gas or hot-air engines, it would probably not be difficult to contrive some continuous automatic arrangement for starting the engine to wind up the weight. I have made trials in ventilation by using the fall of a weight (2 cwt.) descending 30ft. in connection with a small fan blower for the ventilation of a room, and I have also tried by means of the same machine the ventilation of a number of inclosed spaces representing in number aud arrangement the rooms of a house. Another mode would be that of employing two cylinders of capacity sufficient to give the required force, running over pulleys, made to fill automatically with water at the highest cistern of the house, and to empty themselves into a lower cistern. The two cylinders would rise and fall alternately, so as to offer a continuous exertion of power. My results so far have been encouraging, but they are not sufficiently matured to lay before you. There is a plan patented by Messrs. Verity and Co., by which power is obtained from a very small stream of water from a cistern at the top of a dwelling-house, or direct from the water company's mains. Wherever water is available, and the amount of ventilation required is small, this plan is exceedingly convenient and inexpensive. Hot air-engines and gas-engines are now manufactured for machinists of a power low enough to enable them to be employed to give direct motion to a fan or blower without the aid of any intermediary. By using hot-air engines heated by gas a considerable, down to a very small, exertion of power can be obtained, which, with some precautions, may be expected to act with the permanent and regular motion absolutely necessary in any arrangement for ventilation.

After giving a good deal of consideration to the subject, and working at it in various ways by experiment, I came to the conclusion that we should not shrink from endeavoring to grasp, for an application to domestic buildings, the teaching afforded by the results of the best examples of ventilation in this country, such as the Houses of Parliament for instance. In short, that opportunities presented by a thorough and completely controllable system of air circulation should be utilized to the utmost, aiming at more than a mere replacement of breathed by unbreathed air. Pure air united to the climatic conditions most agreeable and desirable for us is what is wanted. One process should enable us in winter time to secure a summer-like condition of air, as well as to maintain a high standard of purity in it throughout the whole of our dwellings.

Nothing but long habit could reconcile us to the extraordinary barbarism of our present arrangements, a small patch of heat and a large space of cold in each room, by which the arrangement of the dinner-table and how to sit at work in one's study become problems it is impossible to solve; but such riddles are mere trifles and quite harmless compared with the important household question as to what condition or period of life, or what infirmity in health, constitutes a valid claim for the indulgence of a fire in the bed-room. The air of half our rooms is that of a cross between the atmosphere of a marsh and a glacier, and many of us leave a warm drawing-room to undress and sleep and dress in the morning during winter under circumstances of pain and peril. Our houses surely cost us money enough to build or to rent; why should we not keep the whole of them in a habitable condition? The labor, much of it of a very heavy and disagreeable kind, necessary for the average number of fires required in a large house is probably equal in the aggregate to the time and care which would suffice to produce, with the proper appliances, any desired climatic condition throughout an entire house; and though the amount of attention required to carry out warming and ventilation in the form I contemplate may be too considerable for application separately to small houses, why could not such houses, if built in rows, or very near together, be supplied with pure air of summer climate from one source, taking precautions to prevent the loss of heat by the employment of non-conducting coats to the main pipes. The important item of saving effected by the avoidance of the destruction caused by stoves and open fires to the furniture, carpets, and hangings, must not be left out of consideration. In point of original cost it is probable that the numerous stoves, with all their attendant paraphernalia of mantelpiece, fenders, hearths, &c., in a house of twenty rooms, would cost as much in the first instance as the machinery for heating and ventilating, while in planning new buildings the arrangements for such a form of ventilation would not add materially to their cost.

I intend to apply these views to some buildings of different requirements I am about to erect. My endeavor will be firstly directed towards means by which the air used for circulation shall be endowed with qualities which will make those buildings comfortable and healthy at all seasons, and in all temperatures. The air will enter freely into a large chamber in which the whole of the appliances for heating the air, moistening it to obtain an agreeable dew point, filtering it from dirt and blacks, and finally dispatching it, by means of a blower or other mode, at any desired speed, will be carried on. The details of arrangement for the circulation of air are, in some respects, those already well known, but in others they are of a special character. Great precaution is necessary to avoid any risk of injury to the quality or agreeableness of the air from the mode of heating it; but a chief cause of the difference experienced in the quality of air heated in various ways will commonly be found to be attributable to a neglect of its dew-point.

In conclusion, I submit that in experiment in ventilation we should keep in view, as desirable of attainment, the following:—

1. That the force of the current, the rate of supply, and quantity of air supplied for the purposes of ventilation of dwellings must be entirely under control.

2. That the quality of all the air supplied for ventilation of dwellings should be capable of easy approximation to any condition of temperature and moisture deemed desirable at any season of the year.

3. That greater influence should be exerted upon the circulation of air in dwellings by the apparatus for inflow than by the means for out-flow of air.

It is stated that in consequence of the new German customs duties legislation, and of other circumstances, a project for the improvement of the Russian railways and the Baltic ports will be speedily carried out. St. Petersburg is to be made a seaport by means of a maritime canal, which will permit the large vessels obliged now to stop at Cronstadt to take in and discharge their cargoes in the Russian capital. The works necessary to make St. Petersburg the largest seaport in the Baltic will be executed in eight years at a cost of 8,000,000 roubles. The port of Libau is also to be enlarged and deepened.

A large amount of money is being expended by the Queensland Government on the Fitzroy River, Rockhampton, in order to make it navigable for coasting steamers and other vessels at all states of the tide. From a report just made by Mr. Nesbit, the Chief Engineer of the Harbors and Rivers Department—it appears that exclusive of the first cost of dredging plant, there has already been expended £35,680, and it is estimated that a further sum £67,467 will be required to complete the work to Central Island, and that if the further works recommended by Mr. Nesbit are carried out, the total expenditure on the improvement of the navigation of this river will amount to more than £145,000.

The Swedish State Railways last summer adopted for the carriage of meat, game, fruit, milk, and similar commodities a number of so-called cooling wagons of a novel type. On the exterior they are painted a pure and brilliant white. In the interior they are fitted with two large ice holders, which are filled from holes in the roof of the wagon. As the ice melts the iced water is conducted through the body of the wagon by iron tubes, which keep the interior at a constantly low degree of temperature. The size of the floor of each wagon is eleven square metres, and the weight they can each carry is eight tons.

ON CAST IRON FOR ENGINEERING PURPOSES.

By Mr. J. S. Brodie (read before the Liverpool Engineering Society).

From "Iron."

Cast iron is now in such general use, it enters so largely into the designs of almost every practical engineer, either civil or mechanical, in the construction of roofs, bridges, machinery, &c., and innumerable other purposes, that no apology need be made for introducing a few practical considerations under the above heading to the attention of this society. Before going into the nature and properties of the material itself, a very brief historical sketch of its development may not be out of place. Without investigating the somewhat debatable question of the prehistoric use of iron, a subject of inquiry more fitting for imaginative archæologists than for matter of fact engineers, it may be taken as being capable of very certain proof that the use of cast iron for structural purposes was almost, if not altogether, unknown before the time of Smeaton. That celebrated engineer is quoted by Tredgold, in his book on "The Strength of Cast Iron," as having in the year 1755 made use of cast iron for structural purposes in connection with mill work in the North of England, but for what particular purpose does not appear. It would also seem to have been used to some extent by Savery and Newcomen in their steam engine and pumps, the cylinders of Newcomen's steam engine being made of cast iron. The art of founding would no doubt be very crude and imperfect in those early attempts, and many improvements were made in this respect by Smeaton, Wilkinson, Tredgold, &c. The first notable example of the application of cast iron on a large scale to bridge purposes was the Coal-brook-dale Viaduct, erected about the year 1755, which crosses the River Severn between Madeley and Brosely. The bridge was erected from castings made by a Mr. Wilkinson, a local ironmaster, from designs prepared by a Mr. Pritchard, an architect of Shrewsbury. Forty-two years afterwards the famous cast iron bridge over the River Wear, at Sunderland, was erected from designs prepared by Thomas Payne. According to the late Sir William Fairbairn, the first application of cast iron beams for the purpose of house construction was that of a fireproof cotton mill erected in the year 1801 by Messrs. Phillips and Lee, of Manchester. The iron beams and columns were designed by Messrs. Boulton and Watt. No improvement seems to have been made on this erection, which continued as a model for all similar structures until Mr. Eaton Hodgkinson commenced his well-known series of experiments into the strength of iron beams and columns at Fairbairn's Works at Manchester in 1827. The results of those experiments were sufficient to considerably modify all previously received opinions on the strength and other properties of cast iron, more especially the tensile strength, which was found by Hodgkinson to have been overstated on the authority of Tredgold, by more than double the actual breaking strength. It is evident, therefore, that the beams and columns designed by Messrs. Boulton and Watt on Tredgold's data must have been allowed a very liberal factor of safety. The adoption of cast iron into general use as a building material for bridges, mill work, &c., may be said to have commenced on the experimental foundation so successfully laid by Mr. Eaton Hodgkinson, who is even up to the present time the chief authority on the strength of cast iron beams and columns.

With this brief introductory historical sketch, the more immediate subject of this paper, viz., "The Nature, Strength, and other Properties of the Material," may now be proceeded with:—Cast iron is obtained by smelting iron ore together with coal, or coke, and limestone, in a blast furnace, at a temperature sufficient to melt the most refractory of those substances. The contents of the furnace are reduced by heat to cast iron and slag, the latter being a glassy substance formed by a combination of the limestone, the earthy ingredients of the ore, and the impurities in the fuel, and is practically a waste product. The cast iron run direct from the blast furnace is usually known as "pig" iron. This pig iron is found on analysis to consist of from 90 to 95 per cent. of iron; from 8 to 2 per cent., by weight, of silicon, sulphur, and other impurities, and from 5 to 2 per cent., by weight, of carbon, either in a state of chemical combination with the iron, producing *white* cast iron; or the carbon may be partly combined and partly mixed in the state of graphite, when it is known as *grey* cast iron.

White cast iron is, as its name implies, of a silvery white, close grained, hard, and very brittle. It is produced by a comparatively smaller quantity of fuel being used in the blast furnace and a corresponding low temperature. It is easily discerned on being tapped from the furnace by its sluggish appearance, and by the way in which it scintillates into the air while running into the moulds. It is subdivided into *granular* and *crystalline*, according to its texture. *Granular* cast iron is sometimes used for castings by being converted into grey cast iron by remelting and slow cooling. *Crystalline* iron, being used only for forge purposes, will not be further noticed. *Grey* cast iron is subdivided into Nos. 1, 2, 3, and sometimes 4. No. 1 is the product of a high temperature in the furnace, caused by a large amount of fuel in the charge. It is the weakest, and is of a large texture, while Nos. 2, 3, and 4, produced at lower temperatures, are successively harder, and of a much closer texture. Grey often merges into white cast iron very gradually, so that the two varieties may often be found in the same fracture. In this case it is known as *mottled* iron, and this class of iron is often found to be very strong.

Generally, it may be stated that white cast iron is the product of a comparatively low temperature caused by deficiency of fuel, while grey is produced at a high temperature and with a larger supply of fuel, and all the intermediate classes from bright white to dark-blue grey are produced by modifications of those conditions. The author's own experience has been that with a large close-topped furnace in average working order and a high temperature of blast, an allowance of about 19 cwt. of coke for white iron, and 21 cwt. for grey, per ton of iron produced, is sufficient.

Without going too minutely into the different qualifications of the various brands for special engineering work, or insisting too much on special mixtures for producing different castings, a short review of the different kinds and their general applicability will now be given. No. 1 is remarkable for the smoothness of its surface in the pig, and melts at a *lower* temperature than any of the others. It contains the largest amount of uncombined carbon, and, owing to its greater liquidity, produces the sharpest and best defined castings where strength is not required, as, for example, in ornamental work. No. 1, when broken, shows a blue-grey color with a coarse grain. No. 2 is less smooth on its surface than No. 1, and is not so liquid when melted. It is closer grained, lighter in the shade when fractured, and is more tenacious. It can be easily worked in the machine, and is preferred for ornamental castings of more strength, such as garden rails, gratings, &c. Nos. 3 and 4 are the kinds most frequently used, either separately or together, or mixed with scrap, for engineering purposes. No. 3 is close grained, the fracture showing a little mottled on the outside, and is distinctly hard and strong while retaining in a great measure the toughness of softer iron. It is invariably selected for heavy shafts, wheels and cylinders, when mixed with soft scrap, and other cases where variable strains are to be expected. No. 4, on the other hand, being much stronger and harder, though less tenacions, is best adapted for very heavy massive castings where the load is more uniform, such as bed-plates, columns, girders, &c., and should never be used where much machine work is intended to be put upon it, as it is too hard for this purpose. *Mottled* iron is seldom used by itself for engineering castings on account of its great hardness, but it is often used with great advantage in mixing it with softer iron to obtain strength with tenacity.

In the early use of cast iron, engineers frequently specified the mixture from which their castings should be made. This was soon found to be inadvisable, for, on the one hand, the founder having deposited the proportions of the mixture specified in the cupola, very properly considered his responsibility to be then in a great measure at an end, throwing all the blame upon the mixture for any damage that might happen to the castings in the various stages of the foundry. On the other hand, the same number of iron was found to differ so much in quality in the same works (to say nothing of the difference between separate works) that it was found in every instance to be very unsatisfactory. Engineers were therefore led to adopt in their specifications standards of strength, appearance, sound, &c., to the finished casting, leaving the founder to employ what pigs he might see fit to produce iron, fulfilling the tests specified when cast.

In considering the subject of the strength of cast iron, only a very general outline can be attempted within the limits of a paper like the present, and the author must refer to the published results of the various experimenters for further detailed information, merely giving general conclusions that have been arrived at from time to time. The subject of strength falls naturally under four separate heads, viz.: Tension, Compression, Transverse Loading, and Torsion. First, as to the tensile strength or resistance to tearing asunder of cast iron. As has already been stated, Tredgold was amongst the first to make experiments on the tensile strength of cast iron, some time about the year 1821. He seems to have made a few owing to the contradictory nature of the tests by direct pulling asunder, but results so obtained, he abandoned them and proceeded to deduce the tensile strength from transverse breaking experiments. For this purpose he caused bars to be supported horizontally at the two ends and loaded in the center, and, assuming the elasticity to be perfect, he deduced from the weight placed on the centre of the bar the tensile stress at the lowest point, thereby obtaining a breaking tensile stress of from 18 to 22 tons per square inch. The fallacy of the results thus obtained were afterwards pointed out by Mr. Eaton Hodgkinson, who showed that owing to the imperfect elasticity of the iron, the neutral line, instead of remaining in the centre of the section, came very near the top at the time of fracture, thereby upsetting Tredgold's calculations. Mr. Hodgkinson then proceeded to make a number of direct experiments on the tensile strength of cast iron bars of from 1 to 4 square inches sectional area, with the following results:

Maximum breaking weight per square inch........................	9.75 tons
Minimum breaking weight per square inch........................	6.00 "
Mean of all the experiments.........	7.37 "

Thus it will be seen that if the iron experimented upon by Mr. Hodgkinson was at all of similar quality to that made use of by Tredgold, of which there seems to be every probability that it was at least equal, then the results of Tredgold were nearly three times in excess of the actual tensile strength. In 1849 the Royal Commission appointed to inquire into the application of iron for railway structures, instructed Mr. Hodgkinson to make further experiments on the strength of cast iron. In connection with this inquiry he tested eighty-one specimens of seventeen different kinds of cast iron, of from three to four inches of sectional area, by direct tearing asunder, with the following results, viz.:

Maximum breaking weight per square inch........................	10.5 tons
Minimum breaking weight per square inch........................	4.9 "
Mean of all the experiments.........	6.8 "

In 1856 the Government authorities made a number of experiments on different kinds of cast iron at the Royal Gun Factory, Woolwich Arsenal. The results were published in a Blue Book in 1858. No attempt was made in these experiments to test mixtures, and it must be observed that as specimens of pig-iron were openly invited from different makers for the purpose of testing, it is not surprising to find the results higher than Mr. Hodgkinson, whose specimens were taken indiscriminately. Eight hundred and fifty specimens, 1.3 inches in diameter, cast in one melting from the pig iron thus obtained, were tested by direct tearing asunder, with results as follows:

Maximum breaking weight per square inch........................	15.3 tons
Minimum breaking weight per square inch........................	4.2 "
Mean breaking weight per square	10.4 "

Professor Rankine, taking the average of a large number of experiments from different sources, gives:

Maximum breaking weight per square inch	13 tons
Minimum breaking weight per square	6 "
Mean breaking weight per square inch	7.36 "

And this will found to be the strength usually adopted by English engineers for ordinary purposes; higher tests being of course required for special work, and when special measures are taken in order to produce a greater tenacity.

Resistance to Crushing.—At an early period cast iron was found to have much greater resistance to crushing than to tearing asunder. As early as 1818 the results of experiments were communicated to the Royal Society by Mr. Rennie on cast iron to resist crushing, which showed a resistance of from 33 to 90 tons per square inch to produce fracture. Mr. Hodgkinson took this branch of his researches up with his accustomed thoroughness, first making a series of thirteen experiments with cylinders $\frac{1}{4}$ inch to $\frac{3}{4}$ inch in diameter, and also with rectangular prisms, with a height of from $1\frac{1}{2}$ to three times the diameter. The experiments were made from different descriptions of cast iron, with results as follows:

Maximum crushing weight per square inch	64.92 tons
Minimum crushing weight per square inch	38 5 "
Mean crushing weight per square inch	48.0 "

Mr. Hodgkinson made experiments on crushing from the same casts as his tensile experiments above quoted from the report of the Iron Structures Commission of 1849, as follows:

Maximum crushing weight per square inch	53.8 tons
Minimum crushing weight per square inch	24.7 "
Mean crushing weight per square inch	38.5 "

The Woolwich authorities made experiments in crushing simultaneously with their tensile experiments, and under the same conditions. Two hundred and seventy-three specimens were treated in a cylindrical form, 0.6 inch diameter, and 1.3 inch high, as follows:

Maximum crushing weight per square inch	62.5 tons
Minimum crushing weight per square inch	19.8 "
Mean crushing weight per square inch	40.6 "

And, finally, Professor Rankine, collating from various authorities, gives

Maximum crushing weight per square inch	64.7 tons
Minimum crushing weight per square inch	36.6 "
Mean crushing weight per square inch	50.0 "

Transverse Strength.—A considerable number of experiments were made at an early date on the transverse strength of cast iron. Those early investigations were made with a view to the application of the material in the form of beams to carry transverse loads. Tredgold quotes several experiments as made previous to his own which have been already alluded to. But the subject was still in considerable uncertainty previous to the searching and valuable experiments of Messrs. Fairbairn & Hodgkinson on the strength of cast iron beams in 1827. These experiments were made chiefly with a view of determining the best and most economical form of section and outline for joist beams for warehouses and mills. But as this subject is a wide field of inquiry of itself, and is without the limits of the purposes of this paper, the author will not enter further into it than to consider the case of a rectangular bar, such as is most frequently used for testing purposes. The author's own practice is to specify a bar of 1 inch square sectional area to be placed on supports 3 feet apart, and is weighted in the center of the bar with the amount specified, which depends upon the quality of the material required. Other dimensions are frequently used by engineers, but the results are easily comparable by the use of the well-known formulæ for rectangular beams, supported at the ends and loaded at the center when

b = breadth
d = depth } All in inches.
c = length between supports
W = breaking weight in tons applied at center.
S = constant denoting the strength of the materials in tons, then $S = \frac{Wc}{bd^2}$.

In Messrs. Fairbairn's & Hodgkinson's

experiments on the transverse strength of cast iron about 270 bars were broken, each bar being 1 inch square and 5 feet in length, placed on supports 4 feet 6 inches apart, and the following results reduced to the value S, in the above formulæ, were obtained, viz:

Maximum transverse breaking weight	.	14 tons
Minimum " "	.	8.6 "
Mean " "	.	10.9 "

The iron for these experiments was taken from nearly sixty different works in the United Kingdom. Experiments on transverse breaking were also made at Woolwich with bars about 2 inches square and 20 inches between the points of support, on 564 specimens, the results being again reduced to the value S, thus:

Maximum transverse breaking weight	.	20 tons
Minimum " "	.	4.6 "
Mean " "	.	12.6 "

Transverse experiments were made by Mr. Robert Stephenson in 1846-47, to determine the most suitable mixtures to be used for casting the large arched girders of the high-level bridge at Newcastle-on-Tyne. The test bars used were 2 inches square in section, placed on supports 3 feet apart, with the following results, viz:

Maximum transverse breaking weight	.	17.2 tons
Minimum " "	.	11.0 "
Mean "		(not given).

A series of tests recently made by the author for cast iron work, made under his supervision, gave as the result of fourteen test bars, representing the same number of meltings, 1 inch square, placed on supports 3 feet apart, and loaded on the center.

Maximum	13.51 tons
Minimum	12.14 "
Mean	12.61 "

of which specimens were exhibited. In testing castings by means of cast specimens it must, of course, always be borne in mind that, owing to the crystallization of chilling of the surface of the iron, a small casting must always be stronger than a larger one, since in the former case the crystallized skin bears to the whole sectional area a much greater proportion than in the latter. Experiments made on this part of the subject have shown that a bar 3 inches square is only relatively half as strong as a bar 1 inch square. In order, therefore, to obtain reliable results from the test bars, the engineer should always specify for a sectional area of the bar equal to the thickest parts of the casting subject to transverse strain.

Torsional strength.—Very few experiments have been made on the torsional strength of cast iron. Those who have experimented have usually done so upon cylindrical specimens fixed at one end and twisted at the other, and the author, for the sake of simplicity of comparison, will confine himself to round bars. In this case let

d=diameter of bar in inches
M=moment of twisting force which will break the bar (in inch bars)
c=co-fficient of resistance to wrenching, in tons

then $C \propto \frac{M}{d^3}$ for the same material.

A few experiments were made by Tredgold on cast-iron shafts, varying from 4 to $4\frac{1}{2}$ inches in diameter, which give values for C, the resistance to wrenching, as follows:

Maximum=2.56 tons
Minimum =2.00 "
Mean =2.34 "

It also appears, from experiments that Mr. Rennie made on round bars, that

Maximum=3.68 tons
Minimum =2.13 "
Mean =2.85 "

From the Blue Book containing the Woolwich experiments it appears that tests were made for torsional strength upon cylinders 3 inches long in the twisted part and 1.8 inches in diameter. 276 specimens were tried as follows:

Maximum=4.4 tons
Minimum =1.65 "
Mean =2.70 "

Having now considered the ultimate strength of cast iron under the several conditions in which it is usually applied for engineering structures, it remains to be seen how these data can be applied to practical use. In order to arrive at reliable conclusions for this, it will first be necessary to see what is the behavior of cast iron under varying weights, less than the ultimate breaking weights; behavior under vibration; and also under varying temperatures within probable working limits. The measure of the elasticity of a material, such as cast iron, may be defined as being the proportion which the temporary extension or compression in the length of any bar, during the application of a force of known amount tending to stretch or compress the bar, bears to its original length, when the elasticity remains perfect, or the bar returns to its original length as soon as the force is removed; while the measure of ductility is the proportion which the permanent extension of any bar after being torn asunder bears to its original length. In the former case the measure is called the modulus of elasticity, which is the weight, usually in pounds, which will stretch a bar 1 inch square to twice its original length, supposing the elasticity to remain perfect; and it will thus be seen to be entirely an imaginary quantity, since it is almost unnecessary to observe that scarcely any material has elastic limits approaching this ideal. Notwithstanding that a considerable number of experiments have been made on the elasticity of cast iron, the subject yet reremains in considerable obscurity; for while Tredgold inferred from his experiments that its elasticity was not impaired by being loaded to one-third of its breaking weight, Mr. Hodgkinson showed that the limit of elasticity was very much below this, but that although a "set" would be produced at this lower limit, yet that the material was not permanently injured by being loaded up to that limit. Acting on this data the Board of Trade Regulations permit cast iron to be loaded with a dead load of one-third of the ultimate breaking weight. Professor Rankine, collating from various sources, gives a modulus of 17 millions, corresponding to a tensile strength of 7.34 tons. The author, from his own experiments on cast-iron bars loaded transversely, has deduced moduli varying from $15\frac{1}{2}$ to 18 millions, or an average of $16\frac{3}{4}$ millions of 14 test bars. The figures given by Rankine may therefore be taken as tolerably near, although it is much to be regretted that more reliable data are not available on this part of the subject, which seems to have been very generally neglected by investigators, and the ultimate deflection taken instead, which is really no measure whatever of the elasticity of cast iron, but is simply some indication of ductility which will now be considered.

The *ductility* of cast iron is, as must be apparent from the nature of the material, very small; the most careful experiments showing $\frac{1}{3}$ to $\frac{1}{8}$ per cent., or an average of $\frac{1}{6}$ per cent. The author, from an average of fourteen experiments on different meltings, found it about $\frac{1}{4}$ per cent. on the specimens exhibited. The smallness of this will be more clearly impressed upon the mind when we remember that wrought iron and mild steel have from 8 to 25 per cent. of ductility. Still, small as it may appear, it should always be carefully noted in testing, as it has a most important bearing on the durability of the casting.

Then as to *vibrations:*—It has been found by several independent investigators that cast iron beams have not been appreciably impaired in strength by the continuance for many years of strains upon them when moderately loaded to within the elastic limits.

With regard to variations in temperature, it appears from the report of the Iron Structures Commission, already alluded to, that there is no appreciable difference in the strength of cast iron from freezing point to about 600° Fah.

A few remarks on the means adopted to protect the surface of castings may not be out of place here. Although cast iron suffers much less from oxidation than wrought iron or steel, owing to the greater proportion of pure iron in the latter, still it must have been in the experience of every one familiar with its use how very soon, comparatively, it is eaten away under certain circumstances. Quite recently the author was called upon to examine some cast iron spouting at one of the Corporation yards in Mill Lane, when he found it completely eaten through, although it had not been in use for more than ten years. Large holes were found in the bottom of the eaves spouting, which in some places was not more substantial than brown paper, while the down-spouts were so much oxidized as to fall to pieces on being lightly touched. Since then the author has been informed of instances in the City of Glasgow in which cast-iron spouting has been rendered useless through oxidation in less than three years. For castings of an ornamental description, among the most successful of the protective coverings is the electrotyping process with metals which have a less affinity for oxygen than for iron—such as copper, zinc, nickel, and sometimes silver and gold. The first-named, copper, has been most extensively employed, as it gives to the largest castings the appearance of bronze—many so-called bronze castings being only cast iron with a copper coating. *Nickel*, on the other hand, by giving to the casting an agreeable white grey color, and having a very small affinity for oxygen, is more used for large exposed surfaces, since it does not oxidize in contact with the air, or even moisture. The *tin* and *zinc* coatings, or "galvanizing," produced by deposition from chloride solutions, are among the most extensively adopted of the metallic coverings. Lastly, of the numerous patented and otherwise infallible paints and varnishes, the new varnish, "Diamond Color," is claimed by its promoters to give a good protection against rust, and certainly it possesses one great merit on account of its greyish blue tint, which gives to the coating its natural appearance, making iron look like iron, which must always be a source of satisfaction. Of the various paints it is only necessary to mention the coal-tar, linseed oil, and common oil paints, all of which are very useful and serviceable, but must be periodically renewed.

The examples of cast iron erections which the author now submits are to be taken more as examples representing the progress of our knowledge of cast iron than as being in any sense a complete list. The first iron bridge erected in this country was, as previously stated, that on the Severn, at Coal-brook-dale. The span is 100 feet, and is semi-circular. The great ribs of the arch, each cast in two pieces, meeting at the crown, are about 75 feet in length. The second iron bridge was built on the same river at Buildwas, in 1795, under the supervision of that father of modern engineering—Thomas Telford. This bridge has a span of 130 feet, and has two cast-iron side arches with 34 feet rise, from which the platform of the bridge is suspended as in a suspension bridge. The third iron bridge was the Sunderland bridge, designed by the celebrated writer, Thomas Payne. The span of this bridge was 236 feet; rise, 34 feet; width of roadway, 22 feet; and there were six ribs. In this bridge the principle of construction adopted differs entirely from the other two just mentioned. Instead of going upon the arch-girder system the iron was treated precisely as if it had been stone, and therefore each rib instead of being in two parts was made in 125 parts. In the place of stone voussoirs forming the arch of a stone bridge, what we may call cast-iron framed voussoirs, each about 2 feet along the curve, and 5 feet in the direction of the radius, were made by bolting straight, or nearly straight, castings together, and proceeding thus as in stonework, only bolting each frame voussoir to its neighbor instead of using mortar. The next cast-iron bridge of importance was Southwark Bridge, completed in 1819 by Sir John Rennie. The span of the center arch of this bridge is 248 feet; rise, 24 feet. The side arches are each 210 feet span. There are eight ribs in each span. The soffits consist of solid masses of cast iron of a depth similar to the voussoirs of a stone bridge. Each principal rib is 6 feet deep at the crown of the arch, and gradually deepens to 8 feet deep at the abutments. Of modern bridges, properly so-called, both the Rochester and Pimlico Bridges are built on the arch-girder system of large segmental castings bolted together. The most recent example that has come under the author's notice is the new bridge over the River Trent at Nottingham, from the designs of Mr. M.O. Tarbotton, M. Inst. C.E., erected in 1871. This bridge consists of three main arches of cast iron, each 100 feet span, and 10 feet rise. Each arch-rib is in three segments bolted together, and also connected to the other ribs transversely. The ribs are 3 feet deep at the springing, and 2 feet 6 inches at the crown, the section being of an I form. In conclusion it may be safely said that not one of those large span cast-iron bridges are likely to be repeated in the future. Our knowledge of cast iron has been got slowly by experience, and that experience teaches us that under circumstances combining tension and vibration it ought not to be used. On the other hand, considering the high superiority of cast iron under compression to wrought iron, and the great disparity in its favor in point of economy, it will always be largely used under circumstances where these conditions are present, and bearing this in mind its nature and properties cannot be too well understood. It has been with this conviction on his mind that the author has been led to lay the above imperfect notes before the society on the present occasion.

THE DISPOSAL OF SEWAGE.

From "The Engineer."

For some time past little had been heard concerning the disposal of sewage. Those who at one time wrote, spoke, and lectured most earnestly on the subject, seem to have entered upon other pursuits. They have apparently abandoned their old love in favor of something new, or else they have lapsed into a condition of apathy, possibly sullen, possibly not unpleasant. There is but one way of explaining this silence. The necessity for disposing of sewage is as pressing now as it was at any time within the last dozen years, and the reason why enthusiastic projectors no longer write to the daily press, or publish books on the subject, is that all their prognostications, almost without exception, have been falsfied, while their anticipations have ended in nothing, save disappointment. At one time it was fiercely maintained that the sewage of each individual possessed a money value of about 8s. per annum. It is not impossible that men may still be found who hold that the sewage of London might be made worth about £1,500,000 a year. In order to impart this value to it, it would be necessary to avoid the use of water as a carrying agent; in a word to adopt what is technically known as the dry system. The concession that water-borne sewage was not worth 8s. per head per anum was wrung from a considerable party only after the lapse of a long period, and by the hard logic of facts. It is now, however, generally admitted that the money value of sewage is much less than it should be according to chemists. But it is still held to possess considerable value, and we now and then have this proposition urged on our attention. Mr. Mechi, for example, not long since endeavoured to turn men's minds once more to the utilization of sewage. It is rumored that the moment commercial prosperity has been sufficiently restored, more than one company will be floated with the object of making a profit out of sewage. It is not improbable, indeed, that the lull in what we may term sewage agitation is nearly at an end; and this being the case, it is worth while to call attention once more to some truths which, however they may be glossed over or distorted by enthusiasts, have certainly never been refuted.

To dispose of sewage at a profit has been tried over and over again with the utmost persistency, and at an enormous cost. The result has been complete failure. In certain isolated cases, where the quantity to be dealt with has been small, or where the conditions have been exceptionally favorable, a small profit has been made either by individuals, companies, or towns; but all attempts to get rid of the sewage of cities, and to realize for those cities even a moderate profit on the cost of the necessary works as well, have been failures. There are two ways in which sewage can be delivered on land. It can be supplied to the agriculturist either in the fluid or in the solid form. Even the most warm advocates of irrigation now admit, what we years ago maintained, namely, that fluid sewage possesses very little more value than plain water. In other words, the dry hungry soils, on which fluid sewage has heretofore been used to most advantage, could be made to produce very nearly as good crops if irrigated from a river or a spring instead of with the sewage of a town. Granting this, however, the fact remains that very good crops can be grown on land irrigated either with water or sewage, and the sewage, consequently, does possess a money value. Solid manure made from sewage is of various values. It has been sold at all prices, from 10s. to £3 per ton; as a rule it is worth probably about £1 10s. per ton. It will be seen, therefore, that those who most earnestly advocate the utilization of sewage have something to go on; unfortunately, for them and for others, they have not enough. The causes of the failure of sewage schemes are very few and very simple. They lie in the difficulty met with in obtaining land adapted for the application of sewage; and the cost of delivery. The first-mentioned obstacle is one of overwhelming magnitude, conflicting interests warring with each other and with sanitary authorities. To find a suitable site for a sewage farm is often a work of great trouble, and the sum demanded for it is invariably very large; nor is there any help for these things. Towns do not as a rule stand on high ground, but in valleys or places close to rivers, and, of course, at the base of the watershed of a district. Thus in most cases the sewage has to be pumped up to a higher level than the town, that it may gravitate to the farm. And so it happens that by the time the farm has been obtained and the necessary machinery has been put down for pumping a mighty sum has been expended. In a few cases the sewage can be made to grow crops enough to pay the cost of pumping; but there is no known instance of a really large town obtaining in this way a return great enough to pay the cost of pumping, and a fair percentage on the capital invested besides. No doubt mistakes have in many instances been made in the selection of sites and the design of machinery; but with all allowances the fact cannot be argued away—that no example can be cited of a large town pumping its sewage on to a farm and making an adequate profit on the outlay. We believe that Mr. Bailey Denton has succeeded in obtaining a satisfactory result in a few cases on a small scale; but with small scale operations we are not now dealing. It is not possible to see how any change for the better can be made in this respect, and we fancy we do not go too far when we say that even the warmest advocates of sewage irrigation now admit that it is impossible to buy or rent a farm and pump sewage on to it at a profit. In a few instances towns have been able to sell their sewage at so much per thousand gallons to farmers, and under these conditions the loss has been small, while in others a trifling profit has been made; but on analysis it will be seen that the result has been brought about because the town has only had to pay for pumping and the interest on the cost of the works, and has not been embarrassed at all about land. In other words, if farms could be had gratis on which to spread sewage, the whole aspect of the matter would be changed for the better, and sewage irrigation might be practised at a good profit. As there is no more chance of this than there is that the sky will fall, we are justified in maintaining that from the application of fluid sewage to land towns and cities have nothing to hope in the way of emolument.

As regards the disposal of sewage in the solid form matters do not look much more hopeful. Although the pail system can be, and has been, used successfully to some extent in certain districts of a few cities and towns, it is totally opposed to the instincts of a very numerous, powerful, and refined class, who will not have it at any price. Those who undertake to dipose of sewage in the solid form must therefore count upon having to deal with it in the fluid form at some time. This has been the ruin of all manner of schemes. Sewage to be worth £2 a ton must be, comparatively speaking, quite dry. Now, it is an easy matter enough to throw down the solid constituents of towns sewage. Settling tanks of sufficient size, and a little lime, or lime and clay properly used, will soon bring about the desired result. The supernatant water can be drawn off as clarified sewage and poured into a river without fear of the consequences. But what is to be done with the enormous mass of foul mud left behind? The really valuable part of the deposit—the ammonia—does not amount to one ton in a hundred, perhaps not to one ton in a thousand. The greater portion of the mud comes from the attrition of the streets. To get the ammonia on to the land it must be taken there in company with the street sweeping, sand and gravel, of no possible value as fertilizers. The water has to be driven away from all this mass of mud, and this can only be done at a cost which raises the value of every ton of the manure far above the price which the farmer can afford to pay for it. The bankruptcy of company after company which has attempted to make a saleable dry manure from sewage demonstrates the accuracy of our statements.

To sum up, the manurial value of sewage has been very much overestimated. The cost of obtaining such valuable constituents as it really does possess in an approximately concentrated form is much too great to enable a profit to be made. Attempts to extract the equivalent of a very inferior guano from sewage find a parallel in the struggle to get a profit out of the crushing and amalgamation of a poor gold-bearing quartz. The rock does not contain gold enough to pay for the labor spent in getting it out. In like manner, sewage does not contain ammonia enough to pay for the cost of getting it in a portable form. Our readers will do well, under the circumstances, to look with the utmost caution at the shares of all companies proposing to make a profit out of the utilization of sewage. We do not assert that it will always be impossible to get an adequate return for money spent on such schemes; but we do assert that it is impossible at present, and under existing conditions. Circumstances may be met with now and then which alter the aspect of the question. For instance, pumping may not be necessary, and land may be had for next to nothing. Then with good management, it is quite possible that a profit may be made on a moderate outlay. Again, the dry system may be in use, and as the cost of getting rid of water is avoided, a profit may be made by converting the contents of pails into *poudrette.* But these are all exceptions to the rule, and any person or company undertaking to deal with sewage must be prepared to get it in the but too familiar liquid form; and to make a profit out of this sewage, manipulate it how we may, is a work which has never yet been accomplished on a large scale. The only chance of making a profit lies in getting the sewage for nothing and suitable land at a very moderate rent—conditions which are very rarely at the disposal of a public company.

ON KEEPING IRRIGATION CANALS CLEAR OF SILT.

By Robert Burton Buckley, Assoc. M. Inst. C. E.

A Paper read before the Institution of Civil Engineers.

There are four methods by which it is possible to exclude more than a desirable proportion of silt from entering an irrigation system: (1.) By works in the river, which will clear the water before it enters the canal. (2.) By so constructing the head sluice of the canal that only water bearing the desired proportion of silt is admitted. (3.) By constructing a depositing basin near the head of, and in, the canal itself, to be cleared either by dredging or by hand labor; or, what is practically the same thing, by making two supply channels from the river to the canal, one to be used while the other is being cleansed. (4.) By constructing a double row of sluices, with a settling tank between, so arranged that the water is drawn off from the lower row carrying the desired amount of silt, and so designed that the deposit in the tank can be flushed back again into the river.

These systems are, of course, applicable under different circumstances. The first can be rarely used, and only when the local conditions are suitable. As for example, where the bed of an inundation canal is perhaps 8 feet or 10 feet above the level of the bed of the river, and which canal is therefore only supplied when the river is in flood. In such a case, if a position for the head of the canal can be selected behind an island covered with brushwood, the top of which is perhaps a little below, or even slightly above the high flood level, it may be well worth the cost to make an artificial connection between the head of the island and the main land, so that all the water entering the canal will first flow through the bay, formed between the island and the main land, entering that bay from below. The velocity of the water in the bay will thus be diminished; the water will deposit silt in the bay instead of carring it into the canal and if the bay be a large one the canal may work for many years without its bed silting up.

The same principle can be employed on large irrigation schemes, by altering the methods now generally adopted in these works. The almost invariable arrangement is, that the weir which stretches across the river, at a height of from 8 feet to 15 feet above the bed, is cut by two sets of under sluices, which are purposely set as close as possible to the head sluices of the canal immediately above the weir; the floors of the head sluices and of the under sluices being at the same level. The under sluices are placed in this position so that silt may not accumulate in front of the entrances to the canal, and thus impede the free entrance of boats to the lock and of water to the canal. This object is attained by opening the under sluices during floods, thus drawing down a rapid stream immediately in front of the openings to the canals, which scours the channel, and removes any deposit that may have accumulated. At the same time that this action of the under sluices clears the approaches to the canal, it causes the canal to be more deeply silted, for the higher velocity produced by the scour of the under sluices removes an extra quantity of silt from the bed of the river, and it is from this rapid and silt-bearing stream, impinging directly on the head sluices, that the canal is supplied. But if the weir were constructed with a double set of under sluices at each end, one set being in the line of the weir, and about 200 feet from the river bank, and the other set some distance lower down the river, but connected to the upper set by a flank wall parallel to the river bank, and if the off-take of the canal were placed immediately above the lower set, the stream flowing to the upper set would not pass in front of the off-take to the canal. The silt-bearing water would pass through the upper set of under sluices with full velocity, while that portion of the river destined for the canal would have its velocity checked immediately opposite the flank wall, and would deposit its silt to a great extent before it reached the head sluices of the canal. To sweep away the silt which would be deposited between the weir and the head sluices, it would be necessary to close the upper under sluices and to work the lower ones. This plan would be rendered most effective by closing the head of the canal for a few hours every week, while the lower under sluices were opened, so that the channel might be kept clean without allowing any silt-bearing water to have access to the canal.

In almost all cases the head sluice of a canal is formed by rows of single shutters sliding in vertical grooves, so that water is always first admitted to the canal from below the shutters, that is at the level of the sluice floor. If the sluices were constructed so that the water was drawn from the top instead of from the bottom of the river, much less silt would be carried into the canal. In rivers which rise moderately, it is best to have a single opening in each vent, covered by three or four shutters sliding in a vertical groove; and each of these shutters should have independent opening gear. In rivers liable to floods rising 30 feet it is necessary to have, in each vent of the sluices, several openings at different levels, each opening being fitted with an independent shutter, so that water can be drawn off at different levels as the flood rises or falls. This way of dealing with the silt can at most be but partially effective; but there are some rivers, carring a small amount of silt, to which this system may be applied with sufficent effect to render the clearance of silt from the canal unnecessary.

The third method is frequently adopted in Indian canals. The first ½ mile of the canal is excavated with a base sufficiently large to cause a great diminution of velocity; the silt is deposited during floods, and excavated when the canal is closed during the summer; or perhaps it is dredged out at a cost even more excessive than that of excavating it by hand.

The fourth method is peculiarly suitable for rivers with a rapid fall. It is also most desirable where a canal runs alongside of the river for some distance before branching off into the country. If this method be adopted, the channel for the first ½ mile or so must be of such capacity that the velocity of the water in it, when carrying the full volume required for the canal, shall not exceed that which will allow of the deposit of the matter in suspension; so that the water, when it reaches the end of this length, shall contain only that proportion of silt which the channels below are arranged to convey to the fields. At the end of this broad channel a sluice will have to be built to carry the full discharge required in the canal with little or no head upon it. The head sluice on the river bank must be so designed that, with only a moderate flood in the river, a sufficient quantity of water can be introduced into the canal to generate a velocity of 3 feet to 4 feet per second in the broad reach, the flushing sluices leading back from this reach to the river being arranged to discharge a corresponding quantity, or even a larger quantity, of water. These sluices might be fitted with falling shutters. The largest flushing sluice should be about 150 feet to 300 feet from the head sluice, for it is about this point that the heavy sand is deposited, and where the greatest scour would be required. This system is the most effective and the least expensive for large schemes. If the head sluice on the river bank be constructed on the principle of taking water from the surface of the river, instead of from below, the minimnm amount of silt will enter the broad reach, and that can, under favorable conditions, be cleared away, by closing the sluices at the extremity of the broad channel for a short time, and opening all the lower shutters of the head sluice on the river bank and the various flushing sluices.

SANITARY FALLACIES.

An Address delivered at Croydon, by Professor W. H. Corfield, M. D.

From "The Builder."

Sanitary science, properly so-called, is a branch of medicine, or, perhaps, I should rather say, a sister science to pathology, for it is the science which studies the causes of diseases, and its place among the sciences is between those of physiology,—the science of life,—and pathology,—the science of disease. We see, therefore, how it is that sanitary science, or hygiene, could only become a science in quite recent times, as it was impossible that it should be scientifically studied until physiology and pathology, upon which it is based, became scientific themselves. The more a branch of knowledge approaches to the character of a true science the more readily are fallacies detected. Although even in the highest science, the most certain branch of human knowledge, mathematics, in connection with which one would think no fallacies could exist, there are still to be found keeping their hold upon the minds of a certain class of investigators, as witnesses,—the supporters of the theory that the earth is flat and that the sun goes round it, the circle-squarers, and the searchers after perpetual motion. If in the highest and most perfect science the power of fallacies does not cease to exist, can it be wondered at that in the youngest, which I will not, however, call the most imperfect, although fallacies which reigned triumphantly while it was yet only an art—the art of preserving the health—and before it became really worthy to be dignified by the name of a science, have been exposed, there are still many others which have a certain, and, in some instances, a most important influence upon the mind of large masses of the community—an influence necessarily for evil? On the other hand, I must point out at once that what is necessary and inevitable in one generation, or at one period of time, may be a mischievous fallacy at a future period and in an advanced state of knowledge . . . . . .

This grand fallacy, the mistaken union of theology and medicine, continued through Mediæval times; and as late as the year 1511, Henry VIII. ordered that physicians and surgeons should be examined by a bishop or vicar-general, with the assistance, it is true, of "such expert persons as they shall think desirable," while the power of granting the degree of Doctor of Medicine remained in the hands of certain high ecclesiastical dignitaries, to a much later period, even if it does not nominally exist now. Through all these dark ages, when the principles of preventive medicine laid down by Hippocrates, Galen, and Celsus were unknown to the multitude, and untaught and unpractised by those whose business it was to teach and practise them—when (more shame to them still) the regulations laid down in that book of which they were the jealous guardians, to which they alone had access, of which they proclaimed themselves the expounders and the teachers, were neglected as completely as if they had never been ordained—filth reigned supreme, the dirty houses were crowded together in narrow streets and courts; the rushes which formed a carpet for the floors were never removed, but piled layer on layer, forming a series of filthy strata often many years old; no attempt was made to check the spread of infectious diseases by the isolation of the sick or by any of the other methods prescribed by Moses; and what was the result? In those ages, and the succeeding ones—the partakers too in the results brought about by this lamentable and gigantic fallacy—plagues held triumphant sway. In the fourteenth century, the Black Death, after traveling over the eastern part of the Old World, reached Europe, and soon arrived in England. It spread over the whole country, and caused such a frightful mortality, that only a tenth of the inhabitants are believed to have remained alive, while "Europe is supposed to have lost an aggregate of 40,000,000" (Dr. Guy). As I have pointed out elsewhere, the only people whom this disease seemed to spare, were those who, however imperfectly, followed the regulations prescribed by Moses, the Jews, whose immunity was so marked that they were accused of spreading the disease by poisoning the water, and were burnt alive by thousands in various parts of Europe. The Black Death reappeared as the Oriental Plague during the sixteenth and seventeenth centuries, and the last time that it appeared in England, in the year 1665, it killed between 70,000 and 80,000 persons in London alone.

But besides the Oriental Plague, a frightful prevalence of other diseases, some of which, as the "sweating sickness" are now unknown; while others, as typhus, scurvy, influenza, dysentery, cholera, and even small-pox, have lost much of their terror, must be included among the consequences of the fallacy which had overspread the world. This fallacy was removed by the gradual divorce of medicine and theology; and the seventeenth century, which had seen the last of the Oriental Plague as far as England was concerned, saw Anatomy raised to the position of a science, by the labors of Vesalius, of Eustachius, of Fallopius, of Malphighi, of Glisson, of Sylvius, of Willis, and of others, almost all of whose names are worthily preserved forever in the names given to various parts of the body, and saw physiology receive the grand impetus given to it by the discovery of the circulation of the blood by William Harvey, and scientific chemistry begin gradually to emerge from the Arabian alchemy.

Thus began again the reign of rational medicine, and from that time to this, the study of methods for the prevention of diseases has been pursued, and in many instances with remarkable success. But although we have got again into the right path, there is, as may be expected, seeing the short time that we have been in it, a vast amount of ignorance prevailing in connection even with the rudimentary principles of sanitary science, and the ignorant multitude are too often led astray by specious fallacies, propounded with some show of reason, and often with great bombast, by persons who have no right to speak with authority on such matters at all, and who are at best "blind leaders of the blind"; but this, we may rest assured, will always be the case, as is shown by the example of mathematical science that I have already instanced. All that we can do, therefore, is to point out such fallacies as they arise, and to warn those who are in danger of being misled by them.

Against all sanitary improvements whatever we find one argument continually brought—that things have gone on in the same way for many years, and there is no reason why they should be changed; and that our forefathers from generation to generation lived under sanitary conditions, and why should we not do the same? That cholera, or enteric fever, or diphtheria has never broken out in a place, or in a particular house, and so it need not be expected! Such are the forms in which this argument meets us at every turn; but those who use it forget that our forefathers died in those places; they forget that in all places which have been made cleaner, from which refuse matters have been removed more speedily, where overcrowding has been abated, where more efficient drainage arrangements have been carried out, the general death-rate has been lowered. When they say that because such a disease as enteric fever has not appeared in a place, therefore it never will, they forget that when cholera or enteric fever is introduced into a place where the conditions are favorable for its spread, where the air is tainted and the water-supply rendered impure with excremental pollution—that in that place, although such diseases may have been absent for so long that their existence has been almost forgotten, they will spread like wildfire and decimate the population. They forget, in fact, that people who are living in the midst of general unsanitary conditions are in a worse plight than people living in the crater of an extinct volcano, for not only may any one of the severest epidemic diseases break out among them at any time, but they are continually sacrificing unnecessary victims to the demon filth. I have mentioned some of the communicable fevers. Now what I believe to be an important fallacy still exists in connection with the poisons of these diseases.

It was formerly thought, and was maintained by Trousseau, that the poisons of these diseases might originate anywhere, at any time under suitable conditions—the specious argument being that having arisen somewhere, at some time or another, there is no reason why they should not originate anywhere or at any time. Without entering into the vexed question of the nature of the poison of such diseases, I will merely point out that this belief is now almost universally scouted with regard to the majority of such diseases. How many persons are there who believe that small-pox or scarlet fever, measles or whooping-cough, arise independently of previous cases of these diseases? And yet we find not a few, supported by the weight of great authority, who believe in the spontaneous origination of the poisons of typhus and enteric fevers, of diphtheria and of cholera. The arguments brought forward to support this position are most of them fallacious in the extreme, and I am bound to say that the arguments advanced to prove the *de novo* origination of the poison of enteric fever are of themselves sufficient to render it in the highest degree improbable. They are, indeed, so weak that no one really capable of judging the value of a scientific argument could from them come to any other conclusion than that the position was untenable. But a practical and very serious mischief has arisen from the spread of these doctrines. We are told that enteric fever is not contagious, and we are told distinctly in so many words that it is rarely, if ever, communicated from person to person; we are told that in the great majority of instances the poison of this disease originates *de novo* in decomposing excremental filth; we are told that the intestinal discharges of patients suffering from this disease do not contain the poison of the disease, although they may be more prone to the special decomposition by which the poison is produced, and the result of all this is, that a large number (I will not say the majority, for I hope it is not so) of the medical practitioners throughout the country take no pains to destroy the poison of this disease at its source—the virus-laden discharges of the intestinal canal. It might be thought that after people were told that living under bad conditions as regards the removal of filth would engender enteric fever among them, they would be even more careful to prevent the possibility of its appearance than if they were told that it would certainly spread if brought to them while living under such conditions; but this is not so, and for the simple reason that the people know well enough that enteric fever does not arise under these conditions. They may be deceived about the general death-rate, but they know perfectly well that a field may have the richest possible soil, may be well-manured and well-watered, but that no wheat will grow in it unless the seed is sown—that a place may be in the most unsanitary condition conceivable for many years, and that enteric fever will not spring up in it. And when they are told that it will, they do not recognize this as a fallacy, but jump to the conclusion that the whole of sanitary science is a philosophical fancy, not worthy the attention of practical people.

But there is still a great fallacy abroad in connection with the question of the removal of refuse matters from the vicinity of habitations. People talk and write as if the water-carriage system and the conservancy system stood upon the same footing—the principle of the one being the *immediate* removal of excretal matters from houses, and that of all the others being, as their name indicates, the keeping of such matters in and about the house for a certain time. The one is a correct principle, the other is a false one; and it is no argument at all to say that where the water-carriage system is badly carried out, the result may be worse than where the conservancy system is carefully managed. In sanitary matters, as well as in everything else, we should follow correct principles. If we do not, but by arguments equally specious and fallacious try to persuade ourselves that "practically speaking" (according to the cant phraseology of the day) better results may be obtained by following false principles, nothing is more certain than that by an inexorable law of nature true principles will assert their position, and we shall be punished for our mistake by being landed in difficulties greater than we had to contend with at the outset. It is a very old and often-exposed fallacy to argue against the use of a thing from the abuse of it, and to argue against the water-carriage system because when surface-drains have been called upon to do the duty of sewers, for which they were not intended, and of which they are not capable, or because the sewage has been turned into the water-courses, which have thus become unfit to supply water for domestic purposes, is an excellent example of this kind of fallacy. I do not say that a well-managed conservancy system is not better than a badly-managed one, nor far better than no system at all, nor do I say that there are not places where the difficulty of carrying out a water-carriage system are not so great as to be almost, if not quite, insurmountable; but I do say that in towns where a water-carriage system is possible, there is no room for choice in the matter. The mischiefs that have been traced to the water-carriage system have occurred from the abuse of it, and not from the proper use of it. Sewer air, about which so much has been written, is injurious when it is collected in badly-ventilated sewers, and allowed to escape from them into the houses; but in an impervious sewer with a proper fall, sufficiently flushed and efficiently ventilated, the noxious ingredients of sewer air are scarcely formed at all, and the air of the sewer is hardly appreciably different from that in the street, while its foulness bears no comparison to that of the atmosphere of many inhabited rooms. The proper way to ventilate sewers is to have a sufficient number of openings leading into them from the surface of the roads, as has been demonstrated over and over again, but I see that the ridiculous practice of having, as far as possible, air-tight sewers, and connecting them with the flues of furnaces, notwithstanding that the fallacy of it was exposed by the Health of Towns Commissioners in 1843, and has been pointed out over and over again ever since, still has its advocates. The commissioners pointed out that in the first place the action of the furnaces was at times so strong as to draw all the water out of the traps on the house-drains, and at other times so ineffectual that the air from the sewers was drawn into the houses through the unsealed traps. They pointed out, too, that in a case where some of the sewers in Battersea had been connected with the furnace of some soap-works, on one occasion coal-gas escaped from a main into the sewer (as has frequently happened since, and not so long ago in the neighborhood of Great George Street, Westminster) and an explosion occurred which blew the works to pieces.

Another important matter in which we are liable to be led astray by false principles, is that of the supply of water for domestic purposes. A man deservedly eminent in his own branch of medicine, told the public not so long ago, from a position that lent weight to his words, that water-analysts and medical officers of health had all gone wrong about water; that the small quantities of organic matter that were discovered in water were matters of no importance at all, and that all water, however pure it was, was contaminated with organic matter as soon as it got into our mouths; that the greater part of our food consisted of organic matter, and that it was ridiculous to condemn a drinking water because it contained small quantities of organic matters. The obvious fallacy of such arguments must be patent to all who have thought upon the subject at all, but to the multitude who allow others to think for them, such fallacies, coming from the mouth of one whose words were entitled to be listened to with respect, were calculated to do a vast amount of mischief. There are organic matters and *organic matters*, and it is not because beef and mutton are good for food that putrifying filth, in however small a quantity, coming from sources likely to be tainted with the poisons of specific diseases, is to be tolerated in water for domestic use; and this leads me to speak of a still greater fallacy in connection with the water supply. We are told that it is not necessary to go to the purest sources for water; we are told that we may take a water that has been once polluted, filter it and give it to the people to drink, that it is a "practically wholesome" water, that no harm can be shown to have resulted from it, and so forth, and we are given averages of its composition to prove that it is "reasonably pure" to be used; but it is not averages we want—we want to know the quality of the worst samples that are supplied. It is ridiculous to tell a man that the average quality of the water given him to drink is good, if on one day in the year he gets water that is "quite unfit for dietetic purposes." But the people are awakening to this matter. They will not be put off by such specious arguments and fallacious reasonings, they will insist on the "practical" carrying into effect of the true principle as laid down by Mr. John Simon.—"It ought to be an absolute condition for a public water supply that it should be uncontaminable by drainage." . . . . . .

Although I do not mean to enter in a statistical discussion, I will mention one or two serious statistical fallacies that are very prevalent, and out of which much capital is made. We are told that in spite of sanitary improvements, the death-rate remains the same; now, considering that "the mortality of the City of London was at the rate of 80 per 1,000 in the latter half of the seventeenth century, and 50 in the eighteenth, against 24 in the present day" (Farr), this statement seems rather audacious. We are also told that the death-rate of London is and has been for some time practically stationary, but since the density of the population is increasing, the death-rate ought to be increasing, whereas it is actually diminishing. Dr. Farr shows that the death-rate of London (calculating from its density) ought to be 35.2 per 1,000 per annum, whereas it is now under 23. Again, we are told that the death-rate from zymotic diseases is stationary; but surely the wonder is that it is not increasing rapidly.

Yet another statistical fallacy: the death-rate of London is very low indeed; we are positively told that this is due to the influx of healthy lives from the country! whereas, as a matter of fact, they make an almost inappreciable difference in the death-rate. The annual influx of immigrants forms in time a permanent addition to the population, but as their death-rate (say that of persons over twenty years of age) differs but little from that of the community at large, or from that of persons under twenty years of age, they scarcely affect the general death-rate themselves at all; if we are required to debit London with the deaths of persons under twenty years of age, of whom the immigrants may be said to be the survivors, we must also credit the population of London with the additional population, under twenty years of age, which would result from an annual number of births equal to that of the immigrants, and of the persons under twenty whose deaths we have taken into account. Thus it can be easily shown that the death-rate is hardly affected at all by immigration.

M. Soret, who pointed out that cerium sulphate, with the aid of the induction spark, exhibited a beautiful violet fluorescence, has continued his researches in the same direction, and finds that in the same manner the solutions of the salts of many earthy metals exhibit the same phenomena. In this category he enumerates lanthanium chloride; didymium chloride and sulphate; terbium, yttrium, erbium, ytterbium chlorides; philippium chloride; thoxium sulphate; zirconium chloride and sulphate; and aluminum and glucinium chlorides.—*The Engineer.*

Fig. 1.

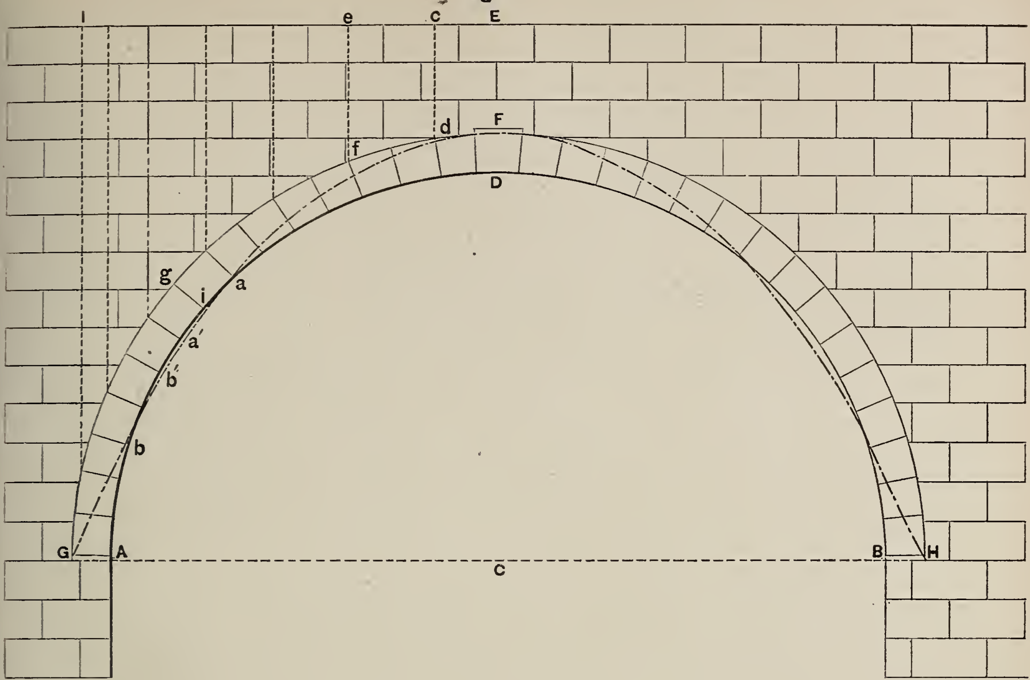


Fig. 5.

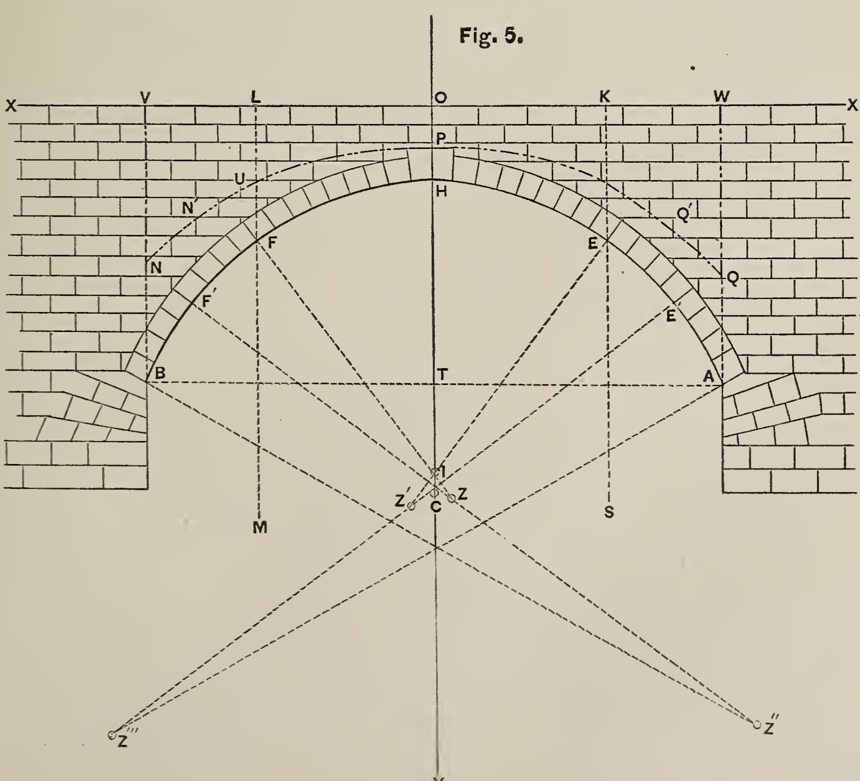


Fig. 2.

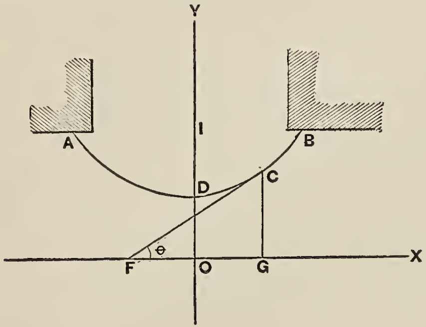


Fig. 3.

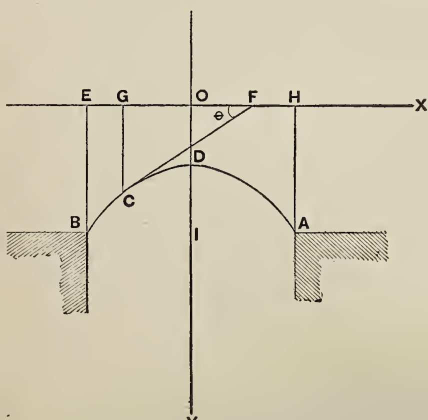
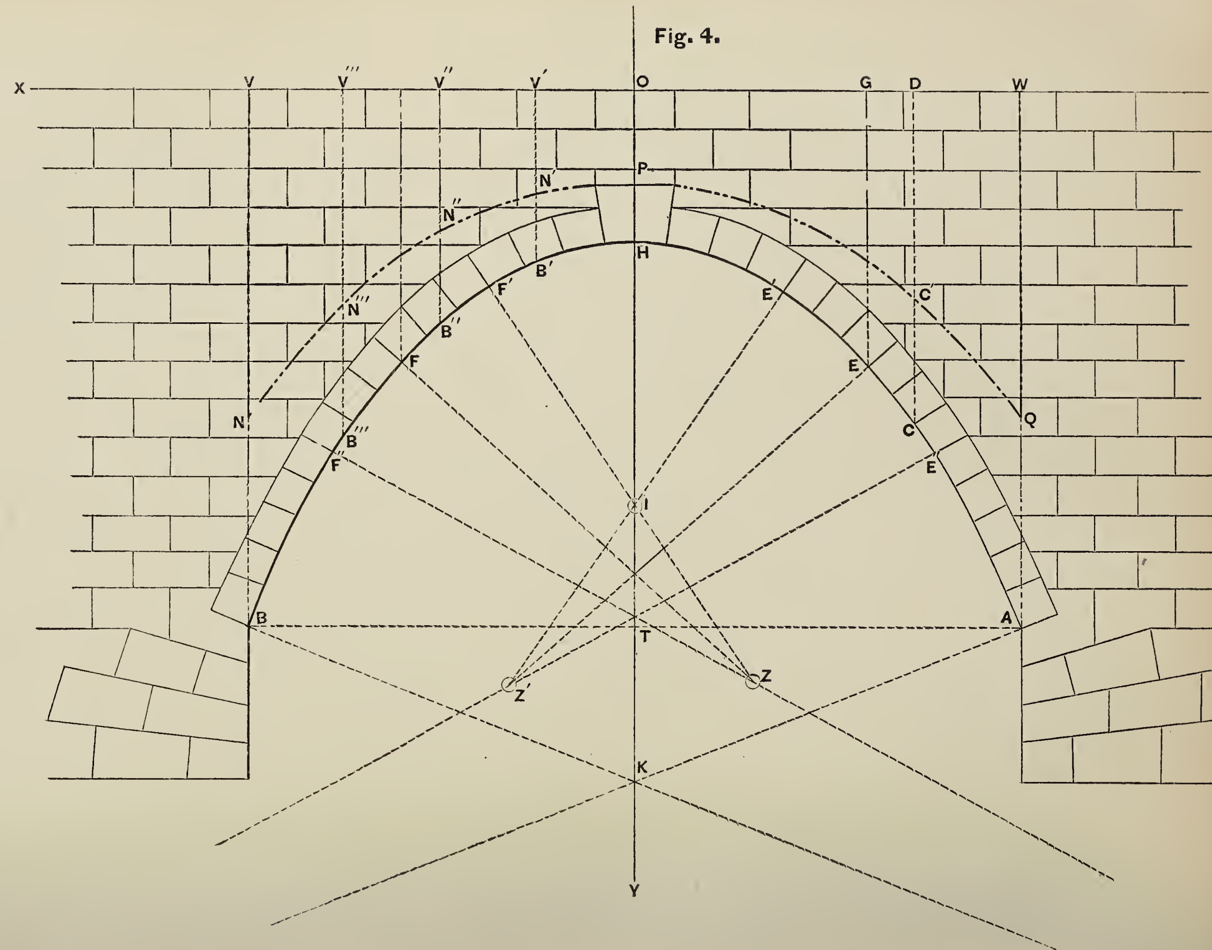


Fig. 4.



ARCH BRIDGES.

By William H. Baker, Civil Engineer.

Some time ago the writer had occasion to investigate the principles upon which the proper construction of the arch, as used in bridges of masonry, depends, and in doing this evolved some facts, which, although well-known to mathematicians, have not perhaps been so generally brought to the notice of engineers in practice. The object of this paper, therefore, is to set forth those facts as clearly and as concisely as possible, with, however, such mathematical deductions as will enable them to be clearly understood, and afford those engineers who are acquainted with higher mathematics an opportunity to examine the accuracy of the reasoning.

The usual form of the intrados or soffit, of a stone arch bridge is circular, the longitudinal section being either a semicircle or a smaller segment.

We will take as an example a full semicircular arch as represented in Fig. 1, having the following dimensions: Let the span, AB, be 40 feet, the rise, CD, 20 feet, and the distance from the crown of the arch to the road bed, DE, 8 feet. These are the data which the engineer generally has from which to design his bridge. The first thing to be determined is the thickness of the arch stones or voussoirs. An empirical rule for the depth of the keystone, which has been used in many designs, is represented by the formula:

$$\text{Depth of keystone} = \tfrac{41}{100}\sqrt{\text{radius of arch at crown.}}$$

This formula has been applied, with slight variation, to some of the largest arch bridge designs in the world, notably the Grosvenor bridge over the Dee, having a span of 200 feet, the London Bridge and the Dean Bridge near Edinburgh. By applying this rule to our example, we find that it gives for the depth of the keystone 1.83 feet. The other arch stones are generally somewhat thinner than the keystone, and it would be fair to presume that if this rule were strictly adhered to in a bridge of the above dimensions, the voussoirs, excepting the keystone, would not have a thickness of more than 1.75 feet. Let us, however, for safety, give all the arch stones a thickness of two feet, increasing the depth of the keystone in the same proportion.

This is probably a fair example of the stone arch bridges throughout the country, and it is now to be seen what the nature of the forces, acting among the arch stones, are. We will suppose the bridge is to be composed of granite, weighing 170 lbs. per cubic foot. The horizontal thrust at the crown of the arch in this case, will be about 19240 lbs. per foot of width of the arch. This can be obtained by finding the center of gravity of the mass, EDAGI, through which its weight acts, tending to turn it about the point, G, which moment is resisted by the horizontal thrust, acting through the point, F. That is: Calling W the weight of the mass, EDAGI, and p the perpendicular distance of its line of action from G; H, the horizontal thrust, we have: $Wp = 22\ H$. (22 feet being the distance to CF.) $\therefore\ H = \frac{Wp}{22}$

Considering, now, this horizonaal thrust to act through the point, F, by combining it with the weights of those sections of EDAGI, into which this mass may be divided by any vertical planes, cd, ef, etc., by the ordinary principles of the composition and resolution of forces we obtain the line, HFG, which is the *Line of Pressures* of the Arch. Wherever this line cuts the joints of the arch stones are the points which receive the pressure of the whole mass of material above. It will be seen, therefore, how important it is that these points should be as near the center of the joints as possible, and it will also be seen by consulting the Fig. how few are the joints at which this point of pressure is near the center.

Indeed, from a to b, the line of pressures passes entirely outside the arch stones; in other words, the ring course of masonry is not thick enough to contain the line of pressures. What is the result? As soon as the line of pressures passes outside of the arch stones at a, it creates a moment, tending to turn the stone a, g, about the point, i, and, consequently, to open the joint, g, i, at g. It, also, by pressing upon the point, i, tends to move the stone, g, a' in a horizontal direction, which movement is resisted by the mass of material always built upon the "hip" of the arch, and equilibrium takes place, with, however, the pressure of the whole mass of material above the joint, g, i, resisted at the point i.

The same thing occurs at the next joint, and the next, until finally the line of pressures re-enters the arch, and terminates at the point, G. This tendency of the joints at the "hip" of the arch, to open at their outside extremities, although resisted so far as to prevent the fall of the arch, is not entirely removed.

An examination of almost any arch bridge will show a slight opening of these joints at their outer extremities and an immense pressure at their inner extremities. The result is that the stone gradually becomes crushed at these latter points and the consequent settling and distortion of the bridge follows. If the ring-course is laid in cement, the cement becomes cracked, water is allowed to get in, and in the winter the bridge is further injured by the action of frost. The same difficulty occurs at the crown of arch, DF, and at the springing, AG, although here the tendency to open is upon the inside, and the tendency to crush upon the outside.

The next question to be considered is: What is the remedy? It certainly is not in using elliptical arches, with the longer axis for the span, as that would evidently increase the difficulty, the form of the curve of pressure being very different from an ellipse. Elliptical arches are often used for bridges, but always at the expense of strength, and sometimes in such a manner as to make the bridge unsafe. One remedy might consist, perhaps, in increasing the thickness of the arch-stones such an amount that the line of pressures could be drawn within the middle third of the joints. It will be seen by Fig. 1 that this line falls outside the arch about 4 inches. This remedy would require, therefore, in this case, the thickness of the arch-stones to be 7 feet, or more than one-third the rise of the arch. Such a thickness is probably impracticable, as no engineer would think of putting such a mass of material into the ring course. Prof. Rankine says that the stability of an arch bridge in which the line of pressures cannot be drawn within the middle third of the joints is very precarious. Yet to, probably, none of the semicircular or elliptical arches, as used in bridges, can this be done. Still these bridges stand and will, very likely, continue to stand, as the large amount of "backing" put upon their "haunches" keep the voussoirs in place. The whole tendency of the bridge, however, is to fall, and certainly such a condition of things, from an engineering point of view, is very bad. Any bungler can put together a lot of wedge-shaped stones, and cover the whole with masonry, in such a manner that the structure shall not *fall*, but the duty of an engineer is to so unite the component parts of the structure that the whole tendency shall be to *stand*, making each joint as nearly as possible perpendicular to the direction of the pressure upon it, and so arranging the surface at each joint that it may receive and resist this pressure to the best advantage.

What, then, must be the form of the soffit of an arch bridge that these conditions may be fulfilled? It remains for us to investigate this problem, and in doing so it will be best to begin at the fundamental principles upon which the proper construction of the arch depends, viz.; The principles of the catenarian curve.

Referring, now, to Fig. 2. let us suppose ADB to represent a thoroughly supple cord or chain hanging from the two points of support, A and B, both being at the same level. This curve is the ordinary catenary, the well-known equation of which, referred to the rectangular axes, OX and OY, is:

$$y=\frac{m}{2}\left(E^{\frac{x}{m}}+E^{-\frac{x}{m}}\right) \quad . \quad . \quad . \quad . \quad (1)$$

in which m, the *parameter* of the curve, is the distance OD, and E is the base of the Naperian system of logarithms, 2.71828. Representing by S any portion of the curve as DC, we also have the following well-known equation:

$$S\frac{m}{2}\left(E^{\frac{x}{m}}-E^{-\frac{x}{m}}\right)\ .\ .\ .\ .\ (2)$$

Let C be any point upon the curve, the co-ordinates of which are:

$$OG=x \text{ and } CG=y.$$

We will now find an expression for the area of the segment contained between the axis of X and the curve, viz., DOGC. Letting A represent this area we have:

$$A=\int_0^x ydx=\frac{m}{2}\int_0^x\left(E^{\frac{x}{m}}+E^{-\frac{x}{m}}\right)$$

$$dx=\frac{m^2}{2}\left(E^{\frac{x}{m}}-E^{-\frac{x}{m}}\right)$$

but by equation (2)

$$S=\frac{m}{2}\left(E^{\frac{x}{m}}-E^{-\frac{x}{m}}\right)$$

therefore $A=sm$ . . . (3); in other words, the area of any segment, DOGC, is *slightly proportional to the arc* DC. If, now, p represent the weight of an unit of length of the cord ADB, the whole weights, W, between D and any point C, will be: $W=ps$, which is also directly proportional to the arc s; hence the following important principle is deduced, viz.: The catenary is the curve of equilibrium, and therefore the proper form for the soffit of an arch bridge composed of homogeneous material, the horizontal road bed of which is at a distance m above the crown of the arch.

Our next step will be to find the value of m. We will now refer to Fig. 3, which is the same as Fig. 2, inverted to conform to the conditions of a bridge. The given data in any particular case may be the half-span, $BI=OE=x_1$ and the vertical distance of the crown above the springing,

$DI=h=OI-OD=y_1-m$ ∴ $y_1=h+m$,

when we shall have by putting these values of x_1 and y_1 into equation (1):

$$h+m=\frac{m}{2}\left(E^{\frac{x_1}{m}}+E^{-\frac{x_1}{m}}\right)$$

when m can be found by a series of approximations, which, added to h will give the distance of the road-bed above the springing.

Or, we may have for data the half span, x_1 and the vertical distance from the road-bed to the springing, y_1, when we have:

$$y_1=\frac{m}{2}\left(E^{\frac{x_1}{m}}+E^{-\frac{x_1}{m}}\right);$$

m can now be found as before and will be the vertical distance from the road-bed down to the crown of the arch. It may be mentioned here that

$$E^{\frac{x_1}{m}}=10^{.4343\frac{x_1}{m}}, \text{ or } \frac{.4343x_1}{m}$$

will be the common logarithm of some number to be found by consulting a table. The above case however, can rarely be used in practice as the conditions are generally too contracted. For instance, the half-span of the arch, x_1, being fixed by the nature of the ground, and the rise, h, being determined by the amount of water or other way required, the height of the road-bed above the springing, y_1, becomes a mathematical deduction and would generally be greater or less than would be practicable. If, however, the span were not fixed by local conditions, we can deduce from our former equation,

$$h+m=\frac{m}{2}\left(E^{\frac{x_1}{m}}+E^{-\frac{x_1}{m}}\right)$$

the value of x_1, the only unknown quantity, as follows:

$$x_1=2.3\,m\log.\left\{\frac{h+m}{m}+\sqrt{\left(\frac{h+m}{m}\right)^2-1}\right\}$$

By applying this formula to our example, that is: making $m=8$ feet and $h=20$ feet, we find the half-span, x_1, to be 15.4 feet, instead of 20 feet, as in the semicircular arch. This case would, probably, seldom be used unless a great height and short span were required. It has all the elements of strength but the conditions are still too contracted.

The next step in our problem becomes, therefore, to find the nature of the curve of equilibrium for the soffit of a bridge of homogeneous material, when the half-span, x_1, the rise of the arch, h, and the vertical distance of the road-bed above the crown, $y_1-h=a$, are all fixed by local conditions. We will still refer to Fig. 3, remembering that in this case, as in the last, the intensity of the weight upon the curve is directly proportional to the ordinate, y. Hence the whole weight upon any portion of the curve, DC, is: area ODCG$\times w = Aw$, where A represents that area, and w the weight of a cubic foot of the material composing the bridge. Let θ represent the inclination of the curve at any point, C, to the horizon. In the figure θ=angle CFG. Let, now, the constant horizontal thrust of the arch, H, be represented by the weight of a certain amount, n^2, of the material of which it is composed, n being the length of the side of the block, its depth, in a direction perpendicular to the plane of the paper, being unity. So that—

$H = wn^2 \therefore \frac{H}{w} = n^2$. Let W be the weight upon any part of the curve DC $\therefore W = wA$.

We now have

$$A = \int_0^x y\,dx \therefore \frac{dA}{dx} = y \text{ and } \frac{d^2A}{dx^2} = \frac{dy}{dx}.$$

But

$$\frac{dy}{dx} = \tan\theta = \frac{W}{H} = \frac{wA}{wn^2} = \frac{A}{n^2} \therefore \frac{d^2A}{dx^2} = \frac{A}{n^2} \ldots (4)$$

Integrating this expression we have

$$A = B\left\{E^{\frac{x}{n}} - E^{-\frac{x}{n}}\right\} \ldots\ldots (5)$$

B being a constant the value of which may be found as follows: Differentiating (5) we have:

$$\frac{dA}{dx} = \frac{B}{n}\left\{E^{\frac{x}{n}} + E^{-\frac{n}{n}}\right\}; \text{ but } \frac{dA}{dx} = y$$

hence

$$y = \frac{B}{n}\left\{E^{\frac{x}{n}} + E^{-\frac{x}{n}}\right\}.$$

But, from the nature of the problem, when $x = o$ $y = a$, therefore

$$a = \frac{2B}{n} \therefore B = \frac{an}{2} \qquad \text{and}$$

$$y = \frac{a}{2}\left\{E^{\frac{x}{n}} + E^{-\frac{x}{n}}\right\} \ldots\ldots (6)$$

which is the equation of the proper curve for the soffit of an arch bridge subjected to the above conditions.

In applying this formula to any particular case the only quantity contained therein, which, thus far, is not known, is n. Its value may be fouud by the remaining condition of the problem, viz: that the half span, x_1, and the height of the road-bed above the springing, y_1, are fixed and known. We proceed as follows: x_1 and y_1 being points upon the curve we have from (6):

$$y_1 = \frac{a}{2}\left(E^{\frac{x_1}{n}} + E^{-\frac{x_1}{n}}\right)$$

from which, by reduction, we obtain

$$n = \frac{x_1}{2.3\log.\left(\frac{y_1}{a} + \sqrt{\frac{y_1^2}{a^2} - 1}\right)} \ldots (7)$$

Let us apply these formulæ to our particular case. We will now refer to Fig. 4. We have for data as before: Half span=AT=x_1=20 feet. Rise=TH =$y_1 - a$=20 feet. Height of road-bed, VW, above crown of arch=OH=a=8 feet. In this case we will suppose the whole material of the bridge, from the soffit to the road-bed throughout, to be stone. From equation (7) we have, by putting in the above values of a, x_1 and y_1:

$$n = \frac{20}{2.3\log.\left\{\frac{28}{8} + \sqrt{\frac{784}{64} - 1}\right\}} = 10.39 \text{ feet.}$$

Therefore by equation (6) we have

$$y = 4\left(E^{\frac{x}{10.39}} + E^{-\frac{x}{10.39}}\right)$$

$$= 4\left(10^{\frac{.4343x}{10.39}} + 10^{-\frac{.4343x}{10.39}}\right)$$

$$= 4\left(10^{.0418x} + 10^{-.0418x}\right) \ . \ (6A)$$

By inserting in this equation different values of x from O, in either direction along the road bed, we obtain corresponding values for y, or the distances from the road bed down to the curve of the intrados. In this way the curve AHB is obtained, which is the proper form for the soffit of a bridge of the above dimensions, composed of homogeneous material.

In practice, however, arch bridges are not usually composed of homogeneous material. The arch stones are, perhaps, composed of granite, and the face spandril walls of the arch built to the level of the road bed of the same material. The space between these walls is usually filled with gravel or broken stones.

The question now arises: In what proportion can these two kinds of material be used together in order to still retain the curve, AHB, as the curve of the equilibrium ?

By inspection of formula (6) it will be seen that the weight of the homogeneous material does not enter into it. Therefore, the form of the curve of equilibrium is independent of the actual weight of the material composing the bridge, it being only necessary that the material should be homogeneous. The curve would be the same, were the bridge composed of the lightest wood, or of the heaviest granite. Therefore w, representing the weight per cubic foot of this ideal homogeneous material, the intensity of the weight upon end point, C, of the intrudos, is: Wy, y being the ordinate, DC. If, now, the distance from D to C, be composed of two kinds of material, one heavier than w, and the other lighter, so that the sum of their weights upon C remains the same as before, the conditions of equilibrium will not be changed. In other words the intensity of the weight upon each point of the curve remains the same. Therefore, if w' be the weight per cubic foot of a material heavier than w, and y' be the amount, CC′ of that material used at any point, C; and w'' be the weight per cubic foot of a material lighter than w, y'' being the amount of DC′, of that material used at the same point, we have:

$$wy = W'y' + w''y'' \quad (8)$$

$$\text{and} \quad y' + y'' = (9)$$

when the road bed is to be level. Referring, now, to our particular case, we will suppose the thickness of the arch stones has been fixed at two feet, excepting the keystone, which is to be three feet in depth. We will suppose those arch stones and a certain distance above them to to be composed of granite of the weight: $W'=170$ lbs. per cubic foot. The remainder of the space between the face walls to be filled with gravel of the weight : $w''=110$ lbs. per cubic foot. To find the line between those two kinds of material, so that the curve of equilibrium shall be the same as at the faces where the loading is composed entirely of granite. Beginning at the crown of the arch, the keystone, HP, is to be three feet in depth, hence, at this point $y'=3$, and $y''=\text{OP}=8-3=5$. $\text{Y}=\text{OH}=8$. ∴ by (8) $8w=3\times170+5x110=1060$. ∴ $\text{W}=132.5$.

AT THE SPRINGING.

Here $y=28$, therefore, by (9)$y''=28-y'$ and by (8)

$$28\times132.5=170y'+3080-110y'$$

$$\therefore y'=10\tfrac{1}{2} \text{ feet},$$

which is the amount of stone BN=AQ to be used as the springing, the remainder, VN=WQ, being gravel. Let us now take the points B′, B″ and B‴, where x equals respectively 5, 10 and 15 feet. The corresponding values of y are: B′V′=9; B″V″=12; B‴V‴=18. Hence by equations (8) and (9) we obtain

B′N′=$3\tfrac{1}{2}$; B″N″≐$4\tfrac{5}{6}$; and B‴N‴=$6\tfrac{3}{4}$.

In this way the curve NPQ is constructed for the *upper limit of the masonry*, upon which the gravel is to be placed. It will be seen that this curve is simply transformed from the original curve, AHB, by making each ordinate

$$y''=\frac{\text{OP}}{\text{OH}}\times y=\tfrac{5}{8}y,$$

that is,

V′ N′=$\tfrac{5}{8}$V′ B′; V″ N″=$\tfrac{5}{8}$V″ B″ &c., &c

Calling this ratio $\frac{\text{OP}}{\text{OH}}$ p we have from (6)

$$y''=py=\frac{pa}{2}\left(\text{E}^{\frac{x}{x}}+\text{E}^{-\frac{x}{x}}\right) \quad . \; . \; (10)$$

which is the equation of the curve NPQ, by which it can always be constructed.

In the above investigation we have shown the form of the soffit of an arch bridge which should be used in order to give it the greatest strength possible. It will be seen that the curve is not an ungraceful one and would probably be considered, by most persons, to possess fully as much architectural beauty as the semicircle. One objection however, to this form of curve might suggest itself in the constant change of curvature and the consequent liability to error upon the part of those intrusted with the cutting of the stones, and perhaps, also, upon the part of those who are to calculate and furnish the dimensions to which these stones are to conform. In order to remedy this evil we will now show that a *five-center arch* may be used, instead of the exact curve represented by formula (6), which will so nearly conform to the latter curve as to practically possess all its advantages and virtues as to strength.

The first step will be to find the radius of curvature of AHB for a few points along the curve. Let r represent this radius. The general expression for the radius of curvature of any curve is, by the differential calculus:

$$r=\frac{(dx^2+dy^2)^{\frac{3}{2}}}{dx\,d^2y} \quad . \quad . \quad . \quad . \quad (11)$$

The equation of the curve AHB is—(6):

$$y=\frac{a}{2}\left(\mathrm{E}^{\frac{x}{n}}+\mathrm{E}^{-\frac{x}{n}}\right).$$

Therefore:

$$dy=\frac{a}{2n}\left(\mathrm{E}^{\frac{x}{n}}-\mathrm{E}^{-\frac{x}{n}}\right)dx$$

$$dy^2=\frac{a^2}{4n^2}\left(\mathrm{E}^{\frac{2x}{n}}+\mathrm{E}^{-\frac{2x}{n}}-2\right)dx^2.$$

$$d^2y=\frac{a}{2n^2}\left(\mathrm{E}^{\frac{x}{n}}+\mathrm{E}^{-\frac{x}{n}}\right)dx^2.$$

$$(dx^2+dy^2)^{\frac{3}{2}}$$

$$=\left\{\frac{a^2}{4n^2}\left(\mathrm{E}^{\frac{2x}{n}}+\mathrm{E}^{-\frac{2x}{n}}-2\right)+1\right\}^{\frac{3}{2}}dx^3$$

$$\therefore r=\frac{\left\{\frac{a^2}{4n^2}\left(\mathrm{E}^{\frac{2x}{n}}+\mathrm{E}^{-\frac{2x}{n}}-2\right)+1\right\}^{\frac{3}{2}}}{\frac{a}{2n^2}\left(\mathrm{E}^{\frac{x}{n}}+\mathrm{E}^{-\frac{x}{n}}\right)} \quad .(12)$$

which is the expression for the radius of curvature at any point x of the curve AHB. At the crown of the arch,

$$x=o \;\therefore\; r_0=\frac{n^2}{a} \quad . \quad . \quad . \quad . \quad . \quad (13)$$

Having found the radius of curvature, the next step will be to find the *direction* of that radius. This is done by the formula:

$$\tan.\,\theta=\frac{dy}{dx}=[\text{By }(6)\,]\frac{a}{2n}\left(\mathrm{E}^{\frac{x}{n}}-\mathrm{E}^{-\frac{x}{n}}\right) \quad . \quad . \quad . \quad (14)$$

At the crown where

$$x=0,\ \tan.\theta_0=0 \;\therefore\; \theta_3=0$$

and the direction of the radius of curvature is vertical and coincides with $_0$Y.

We will now apply these formulæ to our bridge example. At the crown

$$r_0=\frac{n^2}{a}=\frac{(10.39)^2}{8}=13.5 \text{ feet.}$$

The direction of the radius at this point being vertical we lay off from H, in the direction HY, the distance HI=13.5 feet, when I will be the center of curvature of the curve at H.

We will now find the radius of curvature and direction for some intermediate points, E and F. The point selected should be where

$$x=\text{about } \tfrac{3}{5}x_1=(\text{in one case})\ \tfrac{3}{5}\times 20=12.$$

Putting this value of x into equations (12) and (14) we obtain: $r_{12}=25$ feet, and tan. $\theta_{12}=1.09725$ $\therefore$ $\theta_{12}=47°40'$. Therefore from the points E and F where $x=12$ and -12 we draw the lines EZ_1' and FZ, making an angle of 47°40′ with the vertical, upon which we set off the distances $EZ'=FZ=r_{12}=25$ feet. These two points are the centers of curvature of the curve at the points E and F. Join and produce ZI and Z′I and we obtain the points F′ and E′, where the two sections of the curve are to be tangent to each other, that is, where the curvature changes. In the same manner we find the values of r and θ at the springing, where $x=x_1=20$, to be: $r_{20}=83$ feet, $\theta=68°40'$. Laying off from A and B the lines AK and BC, as before, and setting off upon them the distance $r_{20}=82$ feet, we obtain the centers for the curve at the springing, which centers joined with Z′ and Z respectively, and produced give the points E″ and F″.

Thus we see that the curve of the intrados from E′ to F′ is drawn about the center I with a radius of 13.5 feet. The sections E′E″ and F′F″, about the centers Z′ and Z with a radius of 25 feet, and the other two sections about their centers with a radius of 82 feet, there being five centers and three different radii.

In our example the intrados, drawn in this way, so nearly coincides with the original curve, represented by formula (6), that the difference is inappreciable in the drawing, and in all cases it will coincide sufficiently near for practical purposes. Therefore we now have an arch which has all the advantages of strength possessed by the catenary, while every portion of it is constructed about a center, with a known radius, giving it thereby all the advantages of the circular intrados, as each part can be as easily and readily calculated and cut as in the latter.

Let us now take a final case and go through the calculations throughout. We will suppose that we have an arch bridge to design with a span of 60 feet, a rise of 20 feet, and the distance from the crown of the arch to the road-bed to be 8 feet. It is to be understood that these dimensions can always be assumed or determined by the local conditions required, such as the amount of water or other way necessary in each particular case, and the formulæ given above wlll furnish every other dimension. Our voussoirs are to be composed of granite weighing 170 lbs. per cubic foot; the filling to be gravel weighing 110 lbs. per cubic foot. It is not necessary to be very particular about these weights, but it is very easy to ascertain about the average weight of the material to be used.

We have now all the data necessary and can proceed to calculate and make a drawing of one arch. The first step will be to find the value of n, which we do by equation (7). From our data we have: x_1=half-span=30 feet, $y_1=20+8=28$ ft., $a=8$ feet. Introducing these values into (7) and reducing, we have:

$$n=\frac{30}{2.3\log.6.85}=15.62$$

Referring now to Fig. 5, we draw the horizontal line XOX to represent the road-bed, the point O being directly over the crown of the arch. From this point draw the vertical line, OY, upon which lay off OH$=a=8$ feet, and OT$=y_1=28$ feet. H is the crown of the arch. From T draw the horizontal line ATB, upon which lay off AT and BT equal $x_1=30$ feet. A and B are the points of springing of the arch. Our next step will be find the radii of curvature of the required arch at the crown, at the springing, and at one intermediate point. That intermediate point, according to our rule, is where $x=\frac{3}{5}x_1=\frac{3}{5}\times30=18$ feet. The corresponding value of y is found by equation (6′) to be 13.92 feet. Hence, lay off from O, OL and OK, each equal to 18 feet, from which draw the vertical lines LM and KS upon which lay off LF=KE=13.92 feet. The points E and F are thus determined to be two points upon the soffit of the arch. We will now find the radius of the arch at the crown. We use for this purpose equation (13):

$$r_0=\frac{n^2}{a}=\frac{(15.62)^2}{8}=30.5 \text{ feet.}$$

Lay off, therefore, from H, HI$=r_0=30.5$ feet. I will be the center of curvature of the upper section of the arch. The next step will be to find the radius for the points E and F. when $x=18$ and -18. For this purpose we insert in equation (12) the values of a, n and x, when we obtain, by reduction:

$$r_{18}=\frac{[.066(10+\frac{1}{10}-2)+1]^{\frac{3}{2}}}{.0164(10^{.5}+10^{-.5})}$$

$$=\frac{1,91}{.06}=33.5 \text{ feet.}$$

The direction of this radius is found by equation (14) to be:

$$\tan\,\theta_{18}=\frac{4}{15.62}(10^{.5}-10^{-.5})=.72984$$

$\therefore\theta_{18}=36.^\circ\,7'$. Therefore, from the points E and F lay off the lines EZ′ and FZ making the angles SEZ′. and MFZ each equal to 36° 7′. Lay off upon these lines the distances EZ′=FZ.=33.5 feet, and we obtain the centers, Z′ and Z, of the middle sections of the arch.

In the same way we obtain the points Z″ and Z,‴ the centers of curvature of the arch at the springing, and by joining the points, Z″ and Z, and Z‴ and Z′ and producing these lines we obtain the points, F′ and E′. Now with I, as a center, and with a radius, HI=30.5 feet we describe the arc, EHF. With Z and Z′ as centers, and with a radius, FZ= EZ′=33.5 feet, we describe the arcs FF′ and EE′. Also, with Z″ and Z‴ as centers, and with a radius, F′Z″=E′Z‴= 73.82 feet, we describe the arcs BF′ and AE′, which completes the soffit of the arch. The inclination of the arch at the springing, θ_{30} is 60°9′.

It will be noticed that in this particular case the curve corresponds very nearly with the arc of a circle having a radius of $32\frac{1}{2}$ feet, the center of curvature being on the vertical line, OY. The greater the difference between the rise of the arch, h, and the half span, x', the more nearly will the curve obtained, by the above method, correspond to the arc of a circle. So that, in practice, when a bridge is to be designed, having a much greater half span than rise, after having found the proper curve of equilibriums by the above method, the bridge can often be actually constructed, without sensible error, about one center, C, the whole soffit, AHB, being the arc of one circle, the radius of which HC can be easily found in each particular case by the common formula : $R=\frac{h^2+x_1^2}{2h}$.

This, I say, can be done when it has been found by experiment, after having constructed the proper intrados, that such an arc of a circle of the radius, R, actually coincides so nearly with the former curve as to be practically identical with it. Of course, when the rise and half span are equal, this cannot be done as may be readily seen, from Fig. 4. In fact, it is to these latter bridges that this method is particularly adapted, as the semicircular and elliptical soffits are the ones which are particularly faulty in design.

Having determined the form of the soffit, we will now proceed to construct the curve, NPQ, which marks the joint between the masonry and the gravel filling between the face walls. This curve is determined by equation (10):

$$y''=\frac{pa}{2}\left(E^{\frac{x}{n}}+E^{-\frac{x}{n}}\right).$$

In our example we have taken the depth of the keystone PH to be three feet, hence $p=\frac{OP}{OH}=\frac{5}{8}$. Therefore

$$y''=\frac{5}{2}\left(10^{.028x}+10^{-.028x}\right).$$

To find the points, N and Q, we introduce into this equation the value, $x=OV=OW=30$, when we obtain the corresponding value of $y''=VN=WQ=17.65$ feet. Any other point, such as U, may be obtained in the same manner by inserting in the above equation, the proper value of $x=OL$, and obtaining thereby the corresponding value of $y''=LU$. Thus the area included in the figure, VNPQWV, represents the space to be filled between the face walls, with gravel. It will be seen that it makes no difference how much heavier the masonry is than the filling, the soffit represented in the figure will still be the curve of equilibrium, provided the two are joined by such a curve as NPQ.

In fact, as many different kinds of material may be used as desired, if they are joined by curves represented by the equation : $y''=py$.

The horizontal thrust of the arch is given by the equation : $H=Wn^2$, w being the weight per cubic foot of the homogeneous material of an equivalent arch. That is: if W'=weight of granite=170 lbs., and W''=weight of gravel=110 lbs., we have:

$$aw=w'\times PH+w''\times OP$$

$$\therefore W=\frac{PH}{a}w'+\frac{OP}{a}w''$$

$$=\tfrac{3}{8}\times170+\tfrac{5}{8}\times110=132.5 \text{ lbs.}$$

Therefore: $H=132.5\times(15.62)^2=32328$ lbs. per foot of width of the arch.

It is not to be understood as necessary that the extrados of the masonry should conform in practice *exactly* to the curve, NPQ, but that curve is given as a general guide, to be conformed to as nearly as practicable, in order that the curve of pressures of the arch may pass as nearly as possible through the centers of the joints of the arch stones In fact, it might be well in most cases to fill the corners, NN′ and QQ′ with solid masonry, in order to more effectually resist the action of the traveling load.

In conclusion, it may be said, that the result of this investigation is as follows: Given the span, the rise, and the distance between the road bed and the crown of an arch bridge; also, the materials of which the bridge is to be composed, the above formula will determine at once the strongest form for the soffit of the arch, and the proportions of the materials, to be conformed to in each particular case as nearly as the engineer shall consider practicable.

The nearer this conformation, the stronger the stronger the bridge will be, and, conversely the less the conformation, the weaker the bridge.

INDIAN SYSTEMS OF GEOGRAPHICAL MAP MAKING.

By Captain T. H. Holdich, R. E.

From "Royal Engineer Institute."

Of all the nations of the continent of Europe, two only have lately been engaged in geographical operations of a nature that might serve to give us valuable technical information in the particular branch of geodesy, which we call geographical surveying. France has been engaged in such work in Algeria, and Russia in Central Asia, and an examination of the systems of geographical surveying which they follow would doubtless be of very great interest—of great interest, but of little value, for there is this difficulty; in dealing with any foreign system as a source of information to guide us to sound conclusions, every system of mapping (like most systems in general) must be judged to be either good or bad by the excellence or otherwise of its results. But in dealing with French or Russian maps we have no guide whatever to their accuracy. We have obviously no power to apply a check or to sit in judgment on them, and consequently no power at all to say that their system of map making is either better or worse than our own. The most careful examination can lead to no definite conclusion, nor, speaking generally, can we say that what we know, and have known for years of foreign systems has in any material degree assisted to modify or elaborate our own system of survey. In fact, just as no nation has anything like the large interests that England has involved in this branch of science, so England also has the largest experience on which to base a scientific system of topography, and to our own surveys we naturally look to give us the guiding lines for its future extension. But this same difficulty of rightly estimating the value of maps applies to our own maps and our own systems. How are we to decide on the abstract value of any map? Having said of a map that it is accurate and highly artistic, it is quite open to any one else to say that it is inaccurate and most inartistic, and, indeed, this not infrequently happens even in scientific circles. What are the causes of fault in the matter? In the absence of public criticism, where is a fixed standard of excellence to which we may refer?

This is certainly a difficult question, but it seems to me that there are three guiding lines, three conditions or points of departure, as it were, from which we may proceed to adjudge the value of any map about which we can get full information. These three conditions are as follows:—What time was available for its construction? What did it cost? How far is it accurate? And relatively to these points we may either decide in the abstract that a map is good or bad, or we may bring any two maps together and say of one that it is better than another, and so, by means of the map, come to a similar conclusion in respect to the system under which it is produced.

And it may be pointed out that these three principal conditions serve a great deal further than mere points of reference to decide the value of a single map. They govern, one or other of them, every system of map making under every government in the world. If I say that accuracy is the guiding principle of our ordnance maps of England, I shall be sufficiently expressing the sentiment of every one here, without going into details to show the labor and time that is involved in their construction, or to prove that they cost per square mile 15 times as much as the ordnance sheets in India. It is enough to say that they are probably the most accurate maps in existence. Again, in all systems of work adapted to meet the requirements of field service, time fixes sharp limits of the work to be accomplished. To conduct survey operations in company with, or under cover of an advancing field force is one long struggle against time, as anyone must bitterly feel who has taken part in such operations. In India, again, the normal maps of the country are constructed as quickly as may be possible, and as accurately, consistent with a certain fixed expenditure for the whole department. Economy is certainly the guiding principle of Indian surveys, and we consequently find in that land, where salaries are necessarily high and carriage always costly, that maps are yet turned out considerably cheaper than in any continental system.

In looking at any map, then, it is necessary to bear these three conditions in mind, or we may fall into the error of condemning a reconnaissance because it is not a survey, or an excellent geographical map because it will not tally with an ordnance sheet. Simple as they are, it is by no means unnecessary to insist on their recognition. Very unhappy has been the effect of a misapprehension of them even lately in India.

In looking to the future we must first decide on what are the probable conditions under which geographical maps will have to be made. Speaking generally it may, I think, be taken for granted that we shall have wide areas before us of rough uncivilized country, of which a knowledge of the leading features will be firstly valuable from a military point of view.

Time, which means rapidity of action, will be the guiding principle of these first surveys. Short and sharp are the military expeditions of the present day, involving hard marching and quick results. There will be no time to deliberate on the best system of work when that work has once begun. To get all the information one can in the readiest way one can, to turn to the best account small opportunities as they offer themselves, while retaining a general settled system of work which must be capable of much modification—a pliant system as it were—are the requirements of a modern military survey, to produce any definite results when the campaign is over. But looking a little farther into the future it is not difficult to foresee that beyond these first requirements there will be very large tracts of country, over which some more exact survey must pass than is sufficient to fulfill the purposes of a military reconnaissance, and which will be executed with none of the urgency of military movements attending it. Such a survey, in fact, as is now being carried over the native states of Hindustan, and which is extending itself even beyond our frontiers; such as has already been found wanting in Cyprus, and may possibly be very urgently wanted in Asia Minor; such as will most assuredly be required for the highlands of the Transvaal, and must extend itself with the tide of progress in our Australian colonies; and which even may, in a future which we may yet live to see, be spread in some modified form over those interesting countries which have only lately yielded up the great secret of the Nile.

But the urgent requirement of such a survey is usually a long way in advance of the means to pay for it. It frequently happens, indeed, that it is only through the agency of such a survey that the money-producing capabilities of a country can be justly estimated. It is frequently so in India, where the surveys of the native states are made at imperial expense. A useful, sound, geographical map, showing cultivated and cultivable areas, roads, rivers, villages, and valuable forest land, becomes a necessity to the civil administrator of a district, long before there is even a promise of recoupment of the expenses incident on making it. The guiding principle in the construction of such a map is, evidently, economy. It must be made as cheaply as possible, consistently with such a degree of accuracy as may insure its value in assisting the administration of government, or the assessment of revenue.

In considering the value of different systems under which such maps as these are produced, I think, for the present at least, we shall get the largest amount of information from our Indian surveys. Other countries besides England have had to carry geographical surveys through other lands than India, but the means are not forthcoming, as has already been stated, to enable us to estimate rightly the relative value of their maps, nor do such maps as are within our reach bear internal evidence of a higher degree of accuracy under similar conditions of time and cost than do our own Indian maps.

Moreover, the varied surface of India seems to present special advantages of study of almost all characteristics of topography that are likely to be met with in the great unmapped world.

India presents every variety of physical aspect, except that which is most familiar to us in England and Europe, of the most highly cultivated tracts supporting large manufacturing towns—and this, it is hardly necessary to observe, is just what geographical surveyors are never likely to deal with.

We may as well then, at once, begin with an examination of our Indian system of map making, and see wherein it differs from what is generally accepted as the English system, taught in our Military Academies and at Chatham.

Now the Indian system is so simple that, with hardly an exception (the exception will be noted afterwards) all classes of geographical surveying may be summarised in a very few words as—*plane tabling based on triangulation.* It may seem odd that such a well known old surveying instrument as the plane table should not, even yet, have arrived at the point of due appreciation. Used by every European country except England, and used by Englishmen most largely in India, it seems difficult to account for the fact that in England alone its scientific use is practically unknown. Of course, I am aware that it is occasionally used as an adjunct to a prismatic compass, or some other angle-observing instrument, but this is not what I mean by the scientific use of it, and I think I am justified in saying that its capabilities as a scientific instrument are practically unknown. It is due to the memory of one of India's most able Engineers (Colonel Dan Robinson, who lately died at the head of the Telegraphic Department of India) to say that it was his foresight that first pointed out the use of the plane table for Indian surveying. In it he found an instrument so simple that any intelligent native could readily be taught to use it, an angle-observing instrument far exceeding in accuracy the prismatic compass, and a traversing instrument of the greatest value, from the fact of its being totally independent of compass error induced by local magnetic attraction. It has been in use now for many years, during which many officers have learned its capabilities while employed in the survey of our great Indian dependency. As each one, in turn, has been introduced to the system, he has admitted its value to be greater the more thoroughly he has become acquainted with it, so that of every officer in the Indian Survey Department, I think it may now be said, that, were he asked how he would propose to make a map of any rough piece of country before him—from a geographical survey to a rough military reconnaissance, he would unhesitatingly reply, "Let us plane table it." There is not one, no matter how he may have been originally taught, who would adopt any other method.

Now any system which inspires such general confidence as this, is surely worth attention at present, and a fair trial in those large and important fields of work which yet lie before us.

The normal system of Indian surveying is as follows—the system being only modified to meet the necessary requirements of time in the case of military expeditions: the ground is first triangulated from an efficient base, which base in India is invariably furnished by a side of one of the great trigonometrical triangles, which are extended in longitudinal and meridional series over the face of the country. Even in the case of our military frontier expeditions such a base is generally procurable—but we must deal with such surveys as forming a distinct class. The triangulator who uses a 10″ or 12″ theodolite will usually take a plane table with him, and carry on a geographical reconnaissance hand-in-hand with his angular observations. If time admits, he passes over the ground first with the plane table, previous to any instrumental triangulation whatever, as it is in this way that he can best assign, first, the proper position and proportion of points which are to form trigonometrical stations, and next, the subsidiary or secondary points which are fixed by three or more intersections; and can detail the necessary working parties for clearing jungle and erecting signals. Now, though this is merely a rough triangulation chart, its use, when the instrumental work begins, in pointing out the approximate position of signal stations, and in defining the field in which to search for them, when in a background of forest and hill they would often escape detection even with the most powerful instrument, is enormous; and the surveyor will often be surprised to find when the final computations are elaborated, and he is able for the first time to plot accurately by latitude and longitude the position of his trigonometrical stations on his plane table, how accurate this reconnissance, carried out with no aid of compass or protractor (both of which introduce their own class of error) proves to be.

But it not infrequently happens, as I have said, that from the excessive wildness of the country and difficulty of moving about in it, it is most unadvisable to pass over any of the ground twice. The erection of many signals becomes an impossibility, and the selection of trigonometrical stations even a matter of great difficulty. Under pressure of time it becomes necessary to triangulate without any previous reconnaissance whatever. In a country presenting no other features than forest clad peaks, rising with painful similarity of feature and monotony of color from dull forest clad plains below, where the highest tree that may show its top somewhat above the level of those around it becomes the only available signal from day to day through trackless miles of interminable jungle, it would be totally impossible without a plane table chart of this description to unravel the recorded observations to hill peak after hill peak, and finally place each in its proper position. And we must expect much of such work as this in the future. Into the details of triangulation and the nature of signals it is impossible for me to enter. I will merely add that true economy of time and labor consists in carrying a triangulation, once commenced, right through to its completion—never passing twice over the same ground, never revisiting a station once occupied. To attempt first a bit of triangulation, and then a bit of topography, or to carry on the two together, hand in hand as it were, over the same ground, will never lead to a large out-turn of work. The reasons are obvious, but the effect is best noted by the fact that though it would be possible by making steady and direct progress through even the worst country to triangulate, say 4,000 miles in 10 weeks to three months, yet it would never be practicable to do 400 in the first week of the 10. I may further state that all such triangulation being for the subsequent use of plane tablers, we find that one trigonometrical point for each 70 to 100 miles—and one secondary for each 10 square miles is ample for 1-inch work, or about half of what would generally be considered sufficient for topography by any other system of fixings by interpolation.

Neither in India, nor elsewhere in country similar to India, is it necessary (in fact it is not possible, consistently with our guiding principle of economy) to employ only highly skilled labor for the purposes of topography. It is true that a proportion (varying in different districts with the peculiar difficulties presented in the course of survey) of every survey party must consist of skilled draughtsmen, who have sufficient mathematical capabilities to enable them to compute ordinary triangulation, during the season when the climate interferes with the field work, and who complete the final mapping by making fair copies of the field sheets; but if the superintending officer is prepared to compute his own observations, his draughtsmen might be draughtsmen and nothing more. Given that a man has a capability for drawing (a capability which most natives of India possess more or less) he is at once suited with an instrument in his plane table, which enables him to take his place as a surveyor at the minimum cost of expense in teaching. He need know nothing about angular measurement; he need not be able even to read a compass; he never has an observation of any sort to record. The system of fixing his own position by interpolation by the simple process of looking through the sights of his ruler, is one which commends itself to the most ignorant mind for its very simplicity. If three rays intersect he knows he is right (there is just a possible exception to this), if they do not he is wrong, and all he has to learn is which way his table must move in azimuth to correct the azithmuth error and bring the rays together to a point. It is usually the practice to make use of the compass to get the approximate azimuth in the first instance, but the true azimuth is determined, not by it, but by the due intersection of rays. And it must be remembered that this intersection can be made as minutely accurate as it is possible for a pencil point to define it.

Those accustomed to the system of mapping from points fixed by interpolation from prismatic compass observations will remember that there are four distinct origins of error in the system. Firstly, the compass error induced by local attraction. With this error, so far as I know, it is impossible to deal, although it must have fallen within the experience of every geographical surveyor to have found himself often in positions when his compass was absolutely useless. I confess I do not know how this difficulty has been overcome, but it would, in some parts of the world that I have been in, prevent map-making on this system altogether. Secondly, there is the error of compass observation. To what degree of accuracy can an observer take an angle with a prismatic compass? I think 20′′ is probably near the mark. Thirdly, there is the error of a graduated protractor. Assuming that a circular machine-made brass protractor is used, the average error (I have tested many) is about 15′′. Ivory protractors are so absolutely useless from this source of error that I presume nobody uses them. Fourthly, there is the error arising from inaccurate protraction of the observed ray, an error (whatever may be its value) that is proportionate to the length of the ray or line protracted. When this line is finally laid down in the sketch sheet, within what limits can the surveyor guarantee its final accuracy? Shall I say half a degree? I think a degree would be much nearer the truth. And if three such protracted rays do not intersect, to which error of the four must the divergence be assigned, and what is to determine the relative value of these rays? It is clear that fixed points from which to interpolate must be close to the observer, and there must be many of them, from the tendency to increase of error with the length of the ray. And if we fix a limit of distance beyond which no point should be used, the triangulator must remember that the number of points he has to lay down increases in an inverse ratio with the *square* of that distance. Now an average plane table for 1-inch survey work contains about 450 square miles, or four geographical reconnaissance on the $\frac{1}{4}$-inch (a very useful scale for this sort of work) 450×16, or 7200 square miles of country. And if in all this vast area there be four fairly well placed, easily recognized, fixed points previously laid down, which points need not by any means necessarily be visible from every point of that area—but only from positions of important elevation within it—there is quite sufficient means for the topographer to commence his map at once. The four origins of error are reduced to one. There is no compass error, as there need be no compass. There is no protractor either, but there is one source of error in the angular accuracy of the actual observation through the ruler. The value of the plane table as an angle observer has been variously estimated at from 5′ to 10′. I am inclined to put it at 5′. 10′ subtend 15 feet at a mile, and a 15-foot signal would afford a very definite center at that distance. Suppose the azimuthal adjustment to be slightly inaccurate, the intersection of rays from short distances would still be good, and the error unobservable; but as this error increases with the length of the ray, intersections from long distances would gradually become worse till the rays ceased to meet in a point. But the nature of the figure enclosed by them when the intersection fails, at once reveals the extent of the error, which can have but one assignable cause, and the correction is easy. This is why far distant points are used as references for adjustment in azimuth, while it is found advisable to have, if possible, a fair number of points scattered over the board to prevent the loss of time occasioned by the necessity of very fine adjustment. The accuracy of the plane table has been defined as limited only by the fineness of the point of a hard pencil. Compared to the prismatic compass as an angle observer, I should be inclined to reckon it in the ratio of 5′ to 40′ or 50′. Nor must the advantage of working on a steady immovable table, which is truly parallel to (that is to say in true azimuthal relation with) the country to be surveyed, be overlooked. It saves a great deal of troublesome thought and care; while the saving of *time* effected may be easily reckoned up by anyone who will compare the processes of simply observing and drawing a line on a level table, with that of observing with an unsteady compass, and then protracting, first, the angle and then the ray, in a cramped position on an equally unsteady sketch sheet.

Natives of all classes show special facility in acquiring a knowledge of plane tabling, so that a very large share of the topography of India is now laid down by them, and for the future we must look largely to all such local agency in carrying out geographical operations at anything like a reasonable cost.

The net result of the system is this: Admirable 1-inch maps are turned out, often of the highest quality in point of accuracy that is attainable in maps published on the same scale as the field sheets—and always of a good average in this respect—at $\frac{1}{15}$th the cost of the 1-inch ordnance maps of England, or about £2 per square mile. But it might fairly be doubted whether the plane table is suited to all classes of ground alike that are to be found in India, or that might be found in any country possessing about the same wealth of cultivated land. India offers us a large variety. There are large expanses of wide, sandy desert, with details of topography but sparsely scattered through them, and many of the natural features shifting from year to year under the influence of climate. There is the normal condition of hill and plain, with a certain proportion of fine natural landmarks that have to be supplemented by auxiliary signals. There is much of flat and well cultivated plain, difficult to survey from its exceeding flatness, and the preponderance of large trees in clumps, or *topes*, and lastly, there is *very* much of wild jungle-covered country, nothing but rank growth of forest trees and forest grass, where one may ride for many a day's journey without finding a natural landmark of importance, and where every artificial signal has to be hunted for. How are we to deal with country such as this without reducing the value of the survey to that of a mere reconnaissance, or without increasing the cost to excess by clearing lines of traverse and points for interpolated fixings. The experience of the last few years has taught me that this is a very difficult problem, but that it is best solved, after all, by the use of the plane table.

I need not explain in detail all the different systems of traverse, but that is, perhaps, best by which the traverse is laid down on a large scale, on a sheet of paper pinned down over the board, and projected (after reduction to the proper scale) at intervals into the map, whenever any opportunity for check by direct observation to any station or signal on its flank may occur. Traverses may be made to converge to a point, or to "gridiron," and so check one another. Every check that can be gained is brought into play at once, and its effect noted on the ground. Errors of chain measurement are generally detected almost as soon as they occur, and on the whole this system of traverse work may be said to be very fairly satisfactory. So that in all circumstances, and in every class of ground, plain tabling may be classed as the very backbone of Indian surveying.

But having so far described what is done in India, it would be most instructive to examine what has been done by English surveyors elsewhere, under similar conditions of time, cost, and accuracy; such as may guide us to a relative appreciation of the respective results. A certain amount of topographical work was executed in connection with the North American Boundary Commission, but its execution, in the matter both of time and cost, was so entirely subsidiary to the boundary definition, that it seems impossible to separate the two classes of survey. As it was, moreover, but a narrow strip of country, extending nowhere more than a few miles from the boundary which furnished its basis, it does not present an example of so much interest as others that we can find.

The survey of Palestine, which has been conducted during several years by Royal Engineer officers, and worked by Royal Engineer draughtmen, is, under all its conditions, more nearly similar to the geographical work in India, and gives us a more instructive example, because, though of small extent, it has been large enough to test fairly a definite system. With regard to any remarks I may make on this survey, it must be understood that I am indebted entirely to the kindness of Lieut. Kitchener for any information which I possess, and that such remarks refer only to that part of the work which has been conducted by him. But

Lieut. Kitchener's party included some fairly experienced hands, who might be supposed (as I feel sure was the case) to realize the best possible out-turn. The scale of the work is just that of the normal Indian Survey. The object aimed at was finally the same, though there was probably much work, extraneous to the simple surveying, in archæological and other scientific examinationss of sites, and in various reports, for which due allowance must be made. The ground was easy to survey—as I believe is the case throughout Syria. I should have thought it was very easy, but for the assurance to the contrary of those who mapped it, and who ought to know best. But here again we come to the necessity for a definition, and I can only appeal to the decision of those here who may happen to have worked in India, as to the nature of the ground. It is generally open, with here and there strips of sandy plain, almost amounting to desert in their characteristics. There are no forests of any great extent, nothing of the nature of what we generically term "jungle." The face of the country consists partly of hills of tolerably abrupt conformation, and partly of open plain, here and there much cut up with ravines. There are such numbers of natural landmarks that the triangulator laid down about six or seven times as many points as would be furnished in a similar area in India, without ever clearing a ray or erecting an artificial signal. It follows of course, that nowhere could the topographers well put themselves out of sight of three or more such points. Finally, I think I am correct in saying that the topographers could ride to their work over pretty nearly the whole area. The difficulty possibly lay in the amount of detail which (although the final maps show no excess) may have led to confusion in the selection of the most important features. On the other hand, in Sir Rutherford Alcock's address to the Royal Geographical Society last May, we find, with reference to Indian Surveys and to the work of Lieu. Harman, R. E., in particular, "The work was very difficult, incessant rain for many days not only flooded the nullahs and turned the forest paths into streams of mud and water, but brought out myriads of leeches, while cane jungles formed almost insuperable obstacles to laden elephants. Lieu. Harman found magnificient specimens of rubber trees, and in one of them a trigonometrical station was formed 112 feet above the ground to connect his triangulation with that of Lieut. Woodthorpe, R. E. Lieut. Harman was laid up, &c."; and of Lieut. Woodthorpe's work he says "In one place a range of hills is described as nearly level along the top, with no commanding point anywhere, it is sinuous and covered with tall forest trees filled in with a tangled undergrowth of bamboos and canes, through which we cut at the rate of 300 yards an hour." And again "The survey of the river was difficult." In some places "it took three horses to make a quarter of a mile of way," and so on. There is plenty of such work in India; but we see, at any rate, that there must be wide distinctions between different classes of country, and I think we may fairly call Palestine comparatively easy. As to the time occupied and the cost of the field sheets (not of the *final maps* please observe) of the survey, it appears that about 1000 square miles were surveyed between the end of February and the 10th July. This I make out to be about 18½ weeks, and would give an average of about 18 square miles per topographer (for three men) per week, if we leave the topography done by Lieut. Kitchener himself out of account. He could, at any rate, have only devoted a part of his time to the mapping, and we shall get a fairer average, perhaps, by leaving it out of account. The estimated cost was about £900 for that amount of field work, or about 18s. per mile. So far as one can judge from what must at best be only an approxi mate estimate, topographers of about the same technical skill as draughtsmen would turn out a considerably larger area in similar ground in India. I must speak from my own experience only, if I say that 25 to 30 miles would be expected of them. As to cost, if we estimate the cost of the field sheets only (which is what we have at present to deal with) I think we should find the cost of the Indian Survey somewhat greater, say from £1 to 25s. But it must be borne in mind that the salaries of Indian Surveyors range from £60 to £600 per annum, and the salaries of the superintendent from £600 to £2,000, or more; while the conditions of cost must otherwise be so widely different in the two cases that we can institute no fair comparison, and must appeal finally to the test of accuracy. This is a difficult matter to deal with, and it might be fairly said that only a comparison of the field sheets of the respective surveys by competent critics could decide anything, and much do I regret the impossibility of procuring the field sheets at present. I must emphasize the fact of the field sheets affording the only safe and practicable guide in the matter, and emphatically assert that the final maps as reproduced by photo-zincography afford no criterion whatever. But still there is a test of the value of such maps, one constantly applied in India, and held to be, in the main, satisfactory, and this is the record of the number of interpolated fixings of his position made by the topographer in each square mile. I am very far from saying that this is a perfectly unerring guide, nor do I quite agree with a high authority (perhaps the highest) in India, who unquestionably condemmed maps of a hill district, of which he admitted the high artistic merit and apparent consistency of detail, because there were only one or two such fixings per square mile; I can conceive that in that case those one or two were sufficient, but still this is, in the main, a satisfactory test, quite applicable in the case before us. This average in the Palestine survey, I was told, (but I think that careful examination might alter the figures) was about two per mile, which would, on such ground, be considered hardly sufficient in India to complete a fairly accurate reconnaissance. This is just what I understand the Palestine maps claim to be—a reconnaissance of the ground between the Jordan and the Mediterranean. But we most distinctly claim for our Indian 1-inch maps that they are not reconnaissances at all, but surveys, and we should require an average of at least six or seven (rising perhaps to ten) fixings per square mile, for a country such as that, to be as accurately sketched in detail as the scale will admit. And this conclusion is just what I should expect. *Ceteris paribus*, a man using the plane table would certainly be able to fix his position twice as often and sketch twice as much—with far more accuracy—as the man who has to observe each angle with an unsteady compass and protract it with an inaccurate protractor on a shifting piece of tracing paper. Yet another point in connection with the Palestine surveys may be stated, as furnishing some indications of the general style of survey turned out by the use of prismatic compass. Whole villages (without any definite point in them) were found to answer the purpose of signals, or fixed points for observation. I can quite imagine this to be so—but it would not do to offer such a point to a plane table workman—from what has been said it should be clear, I think, that the difference between the two systems, as illustrated by such results as we have been able to get at and compare, amounts to this—the plane tabler will effect a survey where the prismatic compass observer will produce a reconnaissance, and I think such a conclusion represents the situation pretty accurately. It may be said that the reconnaissance is all that is wanted—that it is quite good enough. No map is good enough that could have been much better for the same cost, or that might have been done on half the scale in a quarter of the time with the same amount of accuracy.

We will next consider our Indian system of map-making as applied to the work of a reconnaissance—a field map executed in conjunction with an army in the field under stringent conditions of time. I need not enter into details of the circumstances under which such maps are usually made, but it should be remembered that the time available for such work is usually but a small part of that occupied by the campaign or expedition, as the work of the surveyors must almost always be abandoned on the backward march of the troops from the furthest point gained by the advance, as it is only under cover of an advancing force that commanding points for observation can be occupied, and it seldom happens that surveyors can be allowed to remain behind, or even far from the main column. Time, again, is limited by accidents innumerable, which are certain to arise to cause delay and bar the progress of the work. The importance of being early in the field is very great. The surveyors should be on the ground as soon as they can obtain a footing, as there are casual opportunities of gaining valuable information at the commencement of the campaign, which may never occur again. At present the information gained by the preliminary reconnaissances of the officers of the Quarter-Master General's Department add little or nothing to our geographical knowledge, but there is no reason why it should be so, were those officers invariably acquainted with the use of the plane table.

It is, indeed, most especially in this branch of the surveyor's art (that of military reconnaissance) that the value of the plane table is most strikingly illustrated. Indeed, we may say, that it is only the introduction of the plane table system that has, at last, put into our hands the means of acquiring that widespread and thorough military geographical knowledge which modern science demands. Never again can there be an excuse for turning our backs on a country without such a complete and thorough knowledge of it at our disposal, as shall definitely guide the course of all future campaigns. It is no small thing to reduce to a scientific map the grand chaos of mountain and valley, that bewilders the eye and depresses one with the sense of endless confusion, at the first glance over the mighty northern mountain chains of India, when the only basis for the map are some four or five widely scattered snow peaks whose cold sides defy all human approach. And it is no small system that will help us to do it. The prismatic compass cannot help us here. We must have a broad sheet before us representing at one view many thousands of square miles, or we shall be unable to make one of the few points which are all we can get. We must have the power of minute accuracy to enable us to reduce the scale sufficiently to get those thousands of miles into a portable board. We must have perfect steadiness and no variable compass on those iron hills.

The system which has stood the test of severe trials in India, and promises best towards further developing this branch of science, is but a modification of what has already been described—"plane tabling, based on triangulation."

All along the western and northern frontier of India from Afghanistan to Bhootan, a number of out-lying points have been from time to time laid down by triangulation from within the frontier, comprising peaks of the great Himalayan chains, conspicuous by reason of their height or form, so that it is only necessary for a surveyor to determine what must be the scale of his map, so that, on a plane table of the largest dimensions compatible with portability, he may introduce five or six of such widely scattered points within the limits of his board, for him to have, at once, a practicable, if not always very adequate basis for topography. Bare measurements and preliminary triangulation thus disappear, and a great advantage is gained by work, on a plan which embraces a large area of country, which advantage increases with the number of points thus secured within its limits. This is no new system. Admirable maps have thus been made by Colonel Godwin Austen, of the Bengal Staff Corps, and Captain C. Strahan, R. E., and latter by Lieutenants Leach and Woodthorpe, Harman and Major Badgley. Such work is constantly in progress, and in this way we are gradually extending our geographical knowledge beyond our Indian frontier, and shall, doubtless, eventually have a perfect acquaintance with that great debateable land which lies between us and the Russian frontier. The points of peaks so fixed serve also as points of reference to another class of geographical surveyors altogether. These are the plucky native workmen who under various disguises penetrate into the dreary steppes of Thibet, and bring back at the risk of their lives geographical records of countries absolutely closed to Europeans. This is, indeed, geographical map-making of another and most interesting type, which can hardly as yet be classed as reconnaissance; its high importance has been most fully recognized by the Royal Geographical Society by the award of its medals to Colonel Montgomerie, R. E., Captain Trotter, R. E., and last but not least to the gallant old pundit Nain Sing, native school-master in the district of Kumaon, who may yet live long enough to stir up a rising generation to similar feats of pluck and endurance.

But it does not always happen that we can start with the advantage of points trigonometrically fixed as a basis for map-making of this sort. There are other countries than India equally worthy of the attention of geographers, which have, as yet, no absolutely fixed value of latitude and longitude, whose places on the world's surface may still be called indefinite. Such was the nature of things in Ashanti. I am not aware, though, what (if any) attempt was made to lay down a scientific basis for future geographers in that by no means unimportant corner of geographical *terra incognita.* It does not appear in Colonel Home's report. But the effort was made in Abyssinia, with results too that, in view of the new relations springing up between England and Egypt, and between Egypt and Abyssinia, are growing in importance every day. The line, nearly 400 miles in length, then accurately defined along the main water-parting of North Africa, between the Mediterranean and the Red Sea drainage, served as a base from which peaks were fixed along its flanks, which might even now be sighted from the furthest advanced points in the reconnaissance of the head waters of the Nile, laid down by officers under Gordon Pacha's command. The plane tabler could doubtles bring them together and bridge over a tract of most interesting country, which, at present, divides Egypt from Abyssinia, and that in a land where knowledge of the country means simply security of possession. There is no geographical knowledge in that portion of the globe that will not prove, at no very distant date, of the highest political, if not commercial value. The operations in Abyssinia had to commence with the measurement of a base; observations for absolute latitude, longitude and azimuth were taken at either end, with all the accuracy that the use of first class instruments would admit, the longitude being determined by observations similar to those used in the definition of the North American Boundary. Thus the whole of the work has an absolute value of its own on the earth's surface, which must be accepted as a satisfactory reference for that part of the continent, until observations of a still more rigidly accurate nature can be taken elsewhere in North Africa.

From this base some preliminary points were laid down by triangulation, which gave the basis for topography from the sea coast to Senafé on the high land, where another base and further triangulation carried it on to Antalo. The ends of the bases were connected by an instrumental traverse, which was run right through the entire route from end to end. A treble value by observations for latitude (the route being nearly north and south gave these a peculiar value) and longitude by traverse, and by plane table were thus secured, and it was found that the error by the plane table (on the $\frac{1}{4}$-inch scale) was so small as to be unapparent. A fresh base at Antalo and another at Magdala completed the triangulation necessary, but beyond Antalo the topography became thin and weak. The party was worn out, and there was not an officer with the force capable of using a plane table (though there were many whose services would have been available) and other methods failed miserably when brought to the test of actual practice, at the pace which it was necessary to maintain. In all, however, above 5,000 square miles of actual mapping, and about 400 miles of a traversed route, along the most important line that could have been selected with a view to the future extension of geographical work in North Africa, including the verification of much doubtful information supplied by previous travelers, was secured by three officers and one non-commissioned officer of the Royal Engineers, from the effective strength of which small party a large deduction must be made for sickness. It was a striking illustration of the value of the plane table, and we learnt from this expedition:—1st, that the route traverse might have been dispensed with, as only affording an additional check, and supplying no geographical information whatever; and, 2ndly, that all this, and very much more than this, might have been easily accomplished without the expense of any special survey party whatever, had the officers of the Quarter-Master General's Department been well instructed in the use of the plane table. I have avoided touching on the question of the value of the geographical results thus obtained, either from the geographical or military point of view, because the value has been fully discussed before. Geographers will at once agree that all new information, whensoever and wheresoever obtained, has its value; and the effect of the various topographical features of what has been called the Earth's Crust on the conduct of a campaign, has already been treated with the greatest clearness in Hamley's *Operations of War*, and other standard military works. It is the best method by which to obtain a knowledge of such features with which we have at present to do.

I have also left untouched the question of the adaptation of the plane table to the work of ordinary military reconnaissance, beyond stating that any military officer of the Indian Survey Department would most certainly use the plane table for such work. But it is not the sort of work which has fallen much to the Department, and I should be wandering outside the realms of hard experience and fact into those of suggestion and theory, which I have no wish to do. *Rapidity and accuracy* appear to me to be as fully important in this branch of military survey as in all others, and the plane table would lose nothing by the additional capability of a contouring or leveling instrument for work on a larger scale. Possibly an objection might be raised on the score of portability. We are not in the habit of bestowing much consideration on this point in India. Our 24″ theodolites find their way up the steep sides of almost inaccessible peaks, and we have come to think very little about a pound or so more or less in the weight of an instrument; consequently our Indian plane tables are not very portable. But a plane table is a drawing board on three legs, and it would be an insult to mechanical ability to suggest that it cannot be made just as portable as you please. Messrs. Troughton & Simms have just made one for me, which I could easily carry myself and, on the same construction, I have the satisfaction to find that it might have been made half the weight without in the least detracting from its value.

It is another class of map-making to which we must refer next. There may be weighty reasons (physical or political) which preclude the use of all instruments of the size and nature of a plane table. Where, for instance, observations have to be taken at the risk of life, and progress can only be maintained in secret and under disguise; here we are dependent on compass observations, on routes measured by pacing, on astronomical checks such as can be obtained with a small sextant. Even the pace of an advancing force (as in the case of the Russian advance on Khiva, in which the expedition under General Vereokin marched from Orenburg to Khiva, over 1,000 miles, between the end of February and the beginning of June, reaching Khiva at the same time as Kauffman's expedition from Tashkent) may be too great to admit of much more than this. But this sort of map-making is of, perhaps, the highest importance of all, both from its being within the power of every traveler to accomplish, and from its having lately developed to a remarkable extent by the employment of trained natives for Trans-Himalayan explorations. I think that the experience gained by work done in India within the last ten years points to at least one consideration, which, if well weighed by travelers who aspire to the acquisition of a really scientific knowledge of the geography of the country they explore, might lead to valuable results. This consideration is the readiness with which all classes of natives, whose instincts have been sharpened and habits formed by the constant influences of nature herself, and familiarity with her secrets, seize on the main principles of map-making, and become, with a little pains in teaching, valuable aids to the acquisition of geographical knowledge. The general meagerness of the information supplied by most travelers is doubtless due to an over anxiety to be able to see and attest all geographical facts with their own eyes, added to the temptation of thrilling personal adventure, to leave alone the slow process of compiling the results of observations of others. No one can wonder at this. Still there appear to be points in the progress of all great explorations at which the resources of the white man are at an end, at any rate for a time. But what the white man cannot do, the native frequently can. He is apter at disguising himself, can support himself by ways and means which we know not, and, if at all accustomed to travel, can measure his paces through the long weary day with a persistency and accuracy that sometimes seems marvelous.

Two men, started by different routes to the same point, and bringing back each his tale of paces, will lay down approximately the position of any such point, and if we add to this a slight familiarity with the use of the simplest instruments, such work can be done as you may read of in the reports of the Trans-Himalayan explorers during the last ten years.

Looking at the Transvaal with reference to the 600 or 700 miles of undefined country which lie between its frontier and the head waters of the Nile—or at the most advanced posts on the Nile near Gondokoro, with reference to the debateable land between them and Abyssinia; or the marvellous lake region of which we hear so much, who can doubt that the man who first resigns the hopes and delights of personal adventure for the unpleasant process of shaping out a map from the observations of others, instructed and trained at that frontier, or at those advanced posts will reap a rich reward of geographical knowledge. Another suggestion might possibly be of value. If every traveler, who keeps a chart of his travels, would moumt that chart on a plane table, he would preserve it better, and would certainly at once double his capacity for adding to the topographical records of his map within any given limits of time. As he became more conversant with the use of the plane table, he would more surely find the thin red line across a blank sheet of white paper, which usually shows a traveler's footsteps, expand itself into something like a sound illustration of the topographical features of the country generally.

Briefly what I have endeavored to show is as follows:

1st. Systems of map-making must be judged by their results, of which the relative merit may be gauged by due consideration of the conditions as to time, economy and accuracy under which they are obtained, and, as far as we can judge, the best results have been obtained under the Indian system.

2d. That in all the vast field of mapping which yet lies before us, we are likely to arrive at the best results in the shortest time, and at the least expense, by a careful application of the main principles which have guided us to results in the survey of wild lands similar to those we are likely yet to find.

3d. If we accept this as being, even possibly, true, then it follows that the use of the plane table should become general. It should not merely be an instrument in the hands of a few scientific men, but every officer who may ever be possibly called on to make a reconnaissance, or lay out a route, should be thoroughly master of it. So far as the wide area of India, and its nothern outlying states are concerned, the system is established, and it merely becomes a question of whether a man shall learn his work when he comes to do it for the first time, or have a previous knowledge of it, such as he would have of road or railway making, or barrack building. So far as this is concerned, it may be a matter of no vital importance, but there are times (is there not such an occasion at present?) when the knowledge of the system possessed by a few Engineers at our head-quarters, or a few officers of the Quarter-Master General's Department, would be of the utmost value in the pressure of a campaign, when the burden of this, the most trying and severe work that a military man can engage in, falls upon the back of the over-strained Survey Department of India, when it may be that knowledge of the first importance must escape our grasp because there is no one to reap it. But there are other wide unmapped lands before us. Geographical discovery is the heritage of this age, and close in its footsteps follows geographical mapping. Would it not be well in England to make an honest trial of a well-established system?—a system that has proved its strength—a system finally that has the unhesitating support of every single scientific man who has tried it.

The weight and brittleness of terracotta are great objections to its use in interior architectural decorations and mouldings, and for household utensils and ornaments. To avoid these objections a Spanish South American firm employs cotton pulp covered with a special composition, which contains a soluble varnish. Articles which are made with this material are very light and strong.

ON THE SHAPE AND SIZE OF THE EARTH.*

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I. The Earth as a Sphere.

When surveying is carried on with such accuracy, or over so great areas, that it becomes necessary to take into account the curvature of the earth it is called Geodesy. Were the surface of the earth a plane, as certain ancient peoples supposed, the science of geodesy could never have arisen, since measurements founded on the geometry of Euclid would be capable of determining accurately its geographical features. In fact, however, such measurements become more or less entangled in discrepancies according to the size of the country over which they are carried. For instance, beginning at a certain point, let a line be run due east for half a mile. At any point upon it, its direction, found by common methods, would be the same as at the starting point; but let the line be produced and it will be observed that its direction is deviating from east, and that this deviation becomes more and more marked the farther it be prolonged. If the starting point be at New York, such a line would, in fact, deviate to the south until it crosses the equator in Africa and passes through or near Australia. Again, let three points be taken on the earth's surface at considerable distances apart; the sum of the three angles thus formed, will be found, if measured by an instrument whose graduated arc is placed level at each station, to be greater than 180°. Or, to use an illustration from American surveying: let us consider the system for the division of our public lands, the law concerning which provides that they shall be laid out into townships "six miles square," with sides running duly north and south or east and west. These two requirements, perfectly possible were the earth a plane, are in practice impossible, and the areas of the townships are only laid out "as nearly as may be" to the legal required quantity. From these and many other discrepancies we conclude that the earth's surface is not a plane.

Reasons for supposing the figure of the earth to be globular are given in all the text books on astronomy. They are: the appearance of the top of a light-house before its base to a ship approaching port, the dip of the sea horizon, the elevation of the pole star as we travel north, its depression as we travel back and the new stars that come to view in the south, the analogy of the other planets which seen through a glass seem to be globular, and lastly, the circular form of the earth's shadow as seen in a lunar eclipse. To these must be added the well-known fact that travelers, going ever eastward, pass entirely round the earth, and return again to the point of starting. We regard it then as proved that the earth is globular; that is to say, like a globe, but whether spherical, or spheroidal, or ellipsoidal, or ovaloidal there is thus far no evidence.

The importance of determining the figure of the earth will be apparent when you reflect that map projections of all kinds, and hence the accurate representation of the geographical features of its surface, depend upon it. Particularly to the mariner on the sea is such knowledge valuable, for upon his values of the lengths of degrees of latitude and longitude depends the accuracy of his calculations and his safety. From an engineering point of view we have, indeed, to enquire into the advisable precision to which it is necessary to carry the determination, and this will be alluded to in a following lecture. From a scientific point of view, however, the investigation is not limited by considerations, either of necessity or economy, but is merely one branch of the problem which all science is endeavoring to solve; namely, how and why did this earth and its inhabitants come to exist. In our treatment of the subject we shall look at it mainly in an engineering light, although the scientific aim will not be at all forgotten.

To obtain exact information regarding the figure of the earth, precise measurements on its surface are necessary. The most natural method of procedure is to assume the form to be spherical, and to

* Three lectures, originally prepared for the Civil Engineering Students of Lehigh University as introductory to a course in Geodesy.

test the hypothesis by observations; then, if this be found not satisfactory, to assume it spheroidal, and to make further measurements and calculations. This is the plan which has been followed by scientists, and it is difficult indeed to conceive of one more feasible, since here, as in all science, each step in advance must be from the simpler to the more complex, and be suggested by the knowledge already attained. To assume the form spheroidal at first would be more or less impracticable too, for exact calculations regarding a spheroidal triangle, for instance, imply a knowledge of the eccentricity of the meridian ellipse, the very thing required to be found. In this lecture, then, we regard the earth as a sphere, and proceed to discuss the methods by which its size may be determined.

And first of all we must decide what is the surface whose form is to be investigated. This can be no other than that of the waters of the earth. The ocean covers the greater portion of the globe, its surface is regular compared to that of the land, and although it is agitated by winds and raised in tides, the position of its mean surface is capable of being located very accurately. Moreover, the land is really elevated but little above the sea when compared with the great radius of the globe. The mean surface of the ocean is, then, the spherical surface whose radius is to be determined.

An approximate value for the radius of the globe may be found by observations made at sea upon the distance of the visible horizon. It has been noted, for example, that two points distant about eight miles apart are just visible one to another when each is elevated ten feet above the sea level. Let a plane be passed through these two points, cutting from the globe a circle, and from the center let lines be drawn to the point of tangency and to one of the points of sight, forming a right-angled triangle, from which, with the given data, it is easy to find

$$r = \text{about } 4200 \text{ miles}$$

for the radius of the globe. This value, as every one knows, is in excess by 200 miles or more, yet reflection upon the rude investigation leads us to two conclusions: First that the earth is very large, and, secondly, that no precise estimation of its size can be deduced by observations of this kind. At an elevation of ten feet above the sea level vision is limited to a circle whose radius is about four miles, or whose area is about fifty square miles, while the whole surface is a million times as great. The highest mountains rise about five miles or about one eight-hundredth part of the radius; to conceive this slight elevation of the land imagine the earth to be reduced in size to a globe sixteen inches in diameter, then the tallest mountain would be only one one-hundredth of an inch in height—an amount scarcely perceptible to the eye. Since, then, the earth is so large, slight errors in the determination of the distance of the sea horizon are multiplied in the results, and such errors are particularly liable to occur, owing to the elevation of the visual line by the varying refraction of the atmosphere. The same objection may be made to methods founded on the measurement of the dip of the horizon, or on the vertical angles sometimes taken in geodetic surveys for the determination of the relative heights of stations.

The fact that the sum of the three angles of a geodetic triangle is greater than 180° has been mentioned as a proof that the surface of the earth is not a plane, and this may be also used, under the hypothesis of a spherical surface, to find the radius. It is proved in geometry that the areas of spherical triangles are proportional to their spherical excesses (the excess being the sum of the three angles minus 180°). Thus, if e and e' be the spherical excesses of two triangles, and A and A′ their areas,

$$\frac{e}{e'} = \frac{A}{A'}$$

Let A′ be the area of a tri-rectangular triangle whose spherical excess e' is 90°. Then, since $A' = \frac{1}{2}\pi r^2$,

$$\frac{e}{90°} = \frac{2A}{\pi r^2}$$

in which e must be taken in degrees, and A and r in the same unit of measure. If e and 90° be taken in seconds, the radius is

$$r = \sqrt{\frac{2.90.\ 3{,}600\,A}{\pi e}}$$

Hence r is known when e and A are found by observation. For example, I select two triangles of the primary triangulation of the coast of New England, recorded on page 201 of the U. S. Coast Survey Report for 1865. The first column below contains the names of the stations, the second, the measured angles, each being the mean of a great many observations, and the third the length of the sides in statute miles, each length belonging to the side opposite to the angle against which it is placed.

The sum of the three angles, given in the last line shows the observed spherical excesses to be 26″.687 and 13″.426. The areas of the triangles, being such small portions of the sphere, may be computed as if the triangles were plane and are 1,981 and 943.5 square miles respectively. Then the above formula for the radius gives, from the first triangle,

TRIANGLE No. 84.

Stations.	Angles.	Sides.
Gunstock.........	48° 00′ 55″.063	59.64
Thompson........	70 37 12 .161	75.69
Wachusett........	61 22 19 .463	70.43
	180 00 26 .687	

TRIANGLE No. 80.

Stations.	Angles.	Sides.
Agamenticus.....	67° 35′ 59″.823	50.62
Thompson.......	61 50 53 .264	48.27
Unkonoonuc.....	50 33 20 .339	42.28
	180 00 13 426	

$$r=3913 \text{ miles,}$$

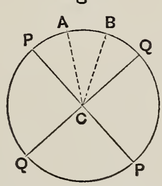
and from the second

$$r=3962 \text{ miles.}$$

This method, though perhaps more accurate than that by vertical angles, is yet far from satisfactory, since the observed spherical excess is subject to errors which are multiplied in the deduced value of the radius. If, for instance, the excess in the first triangle be 26″.6, instead of 26″.687, the radius is increased by seven miles; and since the probable error of these excesses is certainly in the tenths of seconds, better methods should be sought. Thus far the only result of our discussion is that the earth, considered as a sphere, has a radius of *about* 4,000 statute miles.

Regard now the earth from an astronomical point of view, as a globe revolving on an axis from west to east every twenty-four hours, and giving rise to an apparent rotation of the celestial sphere in the opposite direction. The invariable stars describe apparent circles around the celestial poles, and from the measured zenith distances of these stars as they cross the meridian the geographical latitude of any place of observation may be found, by methods detailed in all the treatises on astronomy. Let QP QP in the figure represent a section cut from the earth's sphere by a plane passing through the axis, that is, a meridian section; PP representing the axis, QQ the equator, and C being the

Fig. I.



center of the section regarded as a circle. Let A and B be two places on this meridian whose latitudes have been found, (the angles ACQ and BCQ are these latitudes), then the angle ACB is known. Let also the linear distance between A and B be measured. From these data the lengths of the whole quadrant and of the radius are easily found. Thus let φ be the angle ACB in degrees, and m the distance AB in miles, then

$$\frac{m}{\varphi}=\text{miles in one degree}$$

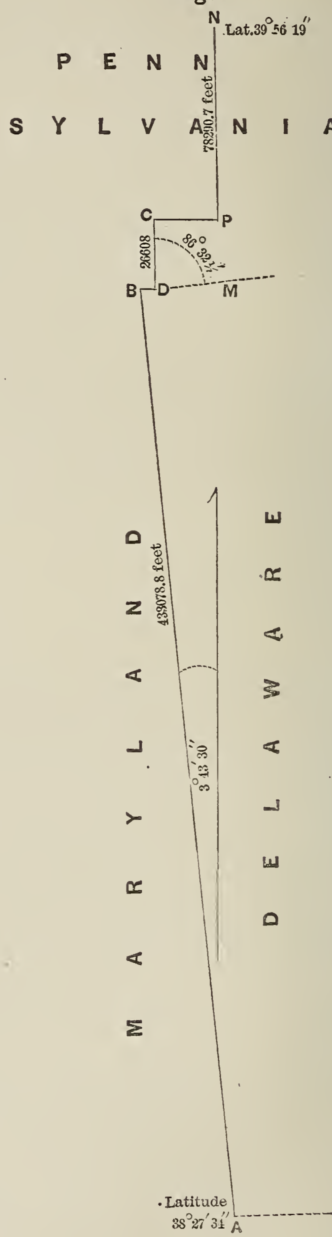
and since the radius of a circle is equal in length to an arc containing 57.29578 degrees,

$$57.29578\frac{m}{\varphi}=\text{radius in miles.}$$

To find, then, the size of the earth, measure the distance between two points on the same meridian, and find their difference of latitude. Such, in its simplest form, is the conception of the geodetic operation, usually called the measurement of an arc of the meridian, the successful execution of which demands the most accurate instruments, the best observers, and long continued labor. The determination of the difference of latitude is now usually made by zenith telescope observations at each station, and is perhaps the easiest part of the work. The length of the curved line of the meridian is more difficult to obtain, since it is usually impracticable to find a line of sufficient length running due north and south, and level enough to be directly measured with rods or chains. Ordinarily the two points are on different meridians, and the length of the meridian, intercepted between their parallels of latitude, is found by calculations from a triangulation carried on between them, the triangulation being itself calculated from the length of a measured base. But as a case where no triangulation is employed is the simpler, we choose such a one for the first illustration.

In the year 1763, the Penn family, proprietor of Pennsylvania and Delaware and Lord Baltimore, proprietor of Maryland, employed two surveyors or astronomers, Charles Mason and Jeremiah Dixon, to locate the boundary lines between their respective colonies. This work occupied several years, and while engaged upon it, Mason and Dixon noted that several of the lines, particularly the one between Maryland and Delaware, were well adapted to the determination of the length of a degree, being on low and level land, and deviating but little from the meridian. Representing this to the Royal Society of London, of which they were members, the latter sent tools and money to carry on the work. The measured lines are shown in the annexed sketch. AB is the boundary between Delaware and Maryland, about 82 miles long and making an angle of about four degrees with the meridian; BD is a short line running nearly east and west; CD and PN are meridians about five and fifteen miles in length respectively; CP is an arc of the parallel, the same in fact as that of the southern boundary of Pennsylvania, the real "Mason and Dixon's line" of ancient American politics. In 1766 Mason and Dixon set up a portable astronomical instrument at A, the southwest corner of the present State of Delaware, and by observing equal altitudes of certain stars, determined the

Fig. 2.



local time and the meridian, after which the azimuth of the line AB was measured, and the latitude of A found by observing the zenith distances of several stars as they crossed the meridian. At N, a point in the forks of the river Brandywine, the zenith distances of the same stars were also measured, from which it was easy to find the latitude of N, or the difference of latitude between A and N. In 1768 they made the linear measurements by means of wooden rectangular frames 20′ long and 4′ high. All the lines had in previous years been run in the operation for establishing the boundaries, and along each of them "a visto" cut, which, says Mason on page 276 of the London Philosophical Transactions for 1768 "was about eight or nine yards wide, and, in general, seen about two miles, beautifully terminating to the eye in a point." Toward this point they sighted the rectangular frames, brought one nicely into contact with the other, made them truly level, and noted the height of the thermometer in order to correct for changes due to expansion. Through the swamps they waded with the wooden frames, but across the rivers they found the distance by a simple triangle. Thus after many wearisome weeks and months the following values were deduced and sent home to England:

Latitude of A=38° 27′ 34″
Latitude of N=39 56 19

Diff. latitude = 1 28 45
AB=434011.6 English feet.
BD= 1489.9 " "
DC= 26608.0 " "
PN= 78290.7 " "
Azimuth of AB at A= 3° 43′ 30″ N. W.
Angle CDB =93° 27′ 30″
CD and NP are true meridians.
CP an arc of parallel about 3 miles long.

Let us now find from these results φ the difference of latitude in degrees, and m the linear distance between the two stations A and N. The value of φ is

$$\varphi = 1.^\circ 47917$$

Now to find m project, as in the sketch below, by arcs of parallels, each line upon a meridian passing through A. Then m=AN,′ and this equals the sum of its parts N′P,′ P′D,′ D′B,′ and B′A,′ thus:

N′P′=NP=78290.7 feet.
P′D′=CD=26608.0 "
D′B′=DG= 89.8 "
B′A′= 433078.8 "

m= 538067.3 feet.

Here D′B′ or DG is found from the triangle BDG, taking it as plane, since its longest side is only 1490 feet long. But in finding AB′ from the triangle BAB′ where two of the sides are more than 80 miles long, AB and AB′ are considered as arcs of great circles, and B′B as an arc of a small circle of the sphere; to do this by the rules of spherical trig onometry involves a knowledge of the radius of the sphere, the very thing required to be found; but it is evident that

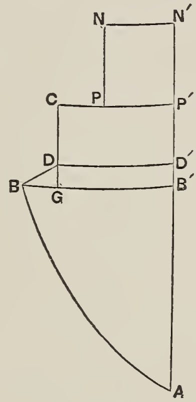


Fig. 3.

only an approximate value is needed, and a few trials will show that the result for B′A will come out the same within a small fraction of a foot, whether the radius of the earth be taken as 3800, 4000 or 4200 miles. The length of one degree of the meridian now is

$$\frac{m}{\varphi} = 363764 \text{ feet} = 68.8945 \text{ miles},$$

from which we find the value

$$r = 3947.4 \text{ miles}$$

as the radius resulting from Mason and Dixon's measurements. Since these were made on land elevated but slightly above the ocean, the result will not be materially lessened for a surface coinciding with the mean level of the waters of the earth.

But as you know very well, a more accurate way of determining the distance between two distant points is by a triangulation. Here a long chain of triangles is formed, all the angles of which are carefully observed. One, at least, of the sides is located in a level plain where it may be very precisely measured by special tools, and by finding the elevation above the ocean of the ends of this base, its length, and hence the whole triangulation may be reduced to that surface. Astronomical observations are made at several of the stations to determine their latitudes and the azimuth of the sides with reference to the meridian. The office work then begins. First, from the known lengths of the measured base and the known angles, the lengths of all the sides of the triangles and the position of each station are computed. A meridian is then conceived to be drawn north and south through the triangulation as also parallels through each of the stations to meet this meridian, and the intercepted portions computed. The sum of these intercepts gives the length of the meridian between the northernmost and southernmost stations. Such operations, for instance, were carried on by French and Spanish scientists in Peru during the years 1736–40. From Cotchesqui to Tarqui, a distance of about 220 miles, they set out stations forming forty-three triangles. Two of the sides of these triangles were carefully measured several times with wooden rods, the northern one near Cotchesqui being 5259.2 toises, and the southern one near Tarqui being 5259.95 toises. From these bases and the measured angles the length of the meridian between the two extreme stations was computed, and found to be

$$m = 176875 \text{ toises},$$

while from the astronomical observations the difference of latitute was

$$\varphi = 3^\circ\ 7'\ 3''.5 = 3^\circ.11764.$$

Hence the length of one degree is

$$56728 \text{ toises} = 68.702 \text{ miles},$$

and the earth's radius is

$$3936.4 \text{ miles}.$$

The toise, we must here say, parenthetically, was an old French measure, now of classic interest on account of its use in this expedition and in the surveys made for deciding on the length of the meter ; it is equal approximately to 1.949 meters, or 6.3946 English feet, or 6.3942 American feet. The length of the degree and the radius resulting from the Peruvian arc, it must be mentioned, are not those of the ocean surface, since it lies on a high plateau, and the surveyors neglected to determine the elevation of their base lines.

It is now time that we should consider our subject more from a historical point of view, and attempt to give some account of the different efforts that have been made to determine the size of the earth. What the Indian or Chinese nations have thought and done we know not; mainly from Europe come all the records, and in early times from Greece alone. Anaximander (year −570) speculated on the shape of the earth and called it a cylinder whose height was three times its diameter, the land and sea being only upon its upper base, a view shared also by Anaxagoras (—460). Plato (—400) thought it a cube. But Aristotle (−340) gives good reasons for supposing it a sphere, and mentions, as also does Archimedes (−250), that geometers had estimated its circumference at 300,000 stadia. Eratosthenes (−230) seems, however, to have been the first to conceive the principles and make the observations necessary for a logical deduction of the size of the sphere. He noticed that at Syene, in Southern Egypt, the sun at the summer solstice cast no shadow of a vertical object, it being directly in the zenith, while at Alexandria, in Northern Egypt, the rays of the sun at the same time of the year made an angle with the vertical of one-fiftieth of four right angles. From this he concluded that the circumference of the earth was fifty times the distance between these two places, and this being, according to the statements of travelers, 5,000 stadia, he claimed for the whole circumference 250,000 stadia. The exact length of the stadia is now unknown, so that we cannot judge of the accuracy of his result; it is probably much too large, since Ptolemy, a learned astronomical writer, who flourished four hundred years later, mentions 180,000 stadia as the length of the circumference; yet the name of Eratosthenes will ever be honored in science as that of the originator of the method of deducing the size of the earth from a measured meridian arc. Posidonias (−90) made also similar observations between Alexandria and Rhodes, using a star, instead of the sun, to find the difference of latitude, and deduced 240,000 stadia for the circumference. But this knowledge of the Grecians was all lost as their civilization declined, and for more than a thousand years Europe, sunk in intellectual darkness, made no inquiry concerning the size or shape of the earth. Only in Arabia were the sciences at all cultivated during this period. There the Caliph Almamoun summoned to Bagdad astronomers, and one of their labors was the measurement, on the plains of Mesopotamia, of an arc of a meridian by wooden rods, from which they deduced the length of a degree to be $56\frac{2}{3}$ Arabian miles—probably about 71 of our miles.

In the fifteenth century, when the first gleams of light broke in upon the darkness of the middle ages, men began to think again about the shape of the earth. Navigators began to doubt that its surface was a level plane, and here and there one, like Columbus, asserted it to be globular. In the sixteenth century, the learned accepted again the doctrine of the spherical form of the earth, and one of the ships of Magellan, after a three years' voyage, accomplished its circumnavigation. With the acceptance of this idea arose also the question as to the size of the globe, and Fernel, in 1525, made a measurement of an arc of a meridian by rolling a wheel from Paris to Amiens to find the distance, and observing the difference of latitude with large wooden triangles, from which he deduced about 57050 toises for the length of one degree. But it was not until the eighteenth and nineteenth centuries that science was able to call to its aid exact processes for executing successfully such difficult observations. In 1617 Snellius conceived the idea of triangulating from a known base line, and thus, near Leyden, he measured a meridian arc which gives 55020 toises for the length a degree. Norwood, in 1633, chained the distance from London to York and deduced 57424 toises for a degree. Picard, who was the first to use spider lines in a telescope, re-measured, in 1669, the arc from Paris to Amiens, using a base line and triangulation, and found one degree to be 57060 toises. This was the result that Newton used when making his famous calculation which proved that the moon gravitated toward the earth. In 1690–1718 Cassini carried on surveys in France, more accurate, probably, than any of the preceding ones, and in 1720 he published the following results:

Arc.	Mean Lat.	Length of 1°.
1.	49° 56′	56970 toises
2.	49° 22′	57060 "
3.	47° 57′	57098 "

and from these it appeared that the length of a degree of latitude increased toward the equator and decreased toward the poles, or, in other words, that the earth was not spherical, but spheroidal, and that the spheroid was prolate or extended at the poles. From the time men had ceased to believe in the flatness of the earth, and had begun to regard it as a sphere, their investigations had been directed toward its size alone; now, however, the inquiry assumed a new phase, and its shape came up again for discussion.

We must here interrupt the historical narrative to say a word about spheroids. A prolate spheroid is generated by an ellipse, revolving about its major axis, and an oblate spheriod by an ellipse revolving about its minor axis. The upper

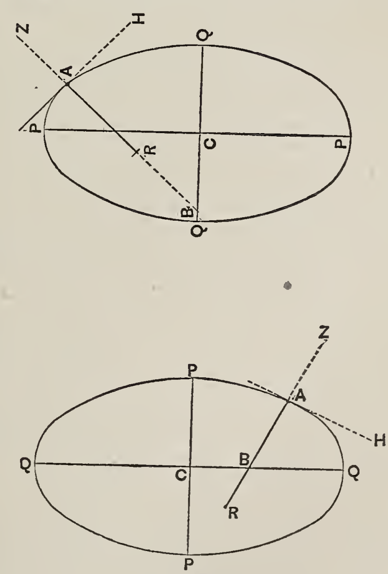


Fig. 4.

figure in this diagram represents a meridian section of the earth regarded as a prolate, and the lower shows it as an oblate spheroid. In each figure PP is the axis, QQ the equator, C the center, A a place of observation, whose horizon is AH, zenith Z, latitude ABQ, and radius of curvature AR. Now, if the earth be regarded as a sphere and its radius be found from observations made near A, the value AR will result, it being always 57.2958 times the length of one degree of latitude at A. In the prolate spheroid the radius of curvature is least at the poles and greatest at the equator, and the reverse in the oblate. Hence if the lengths of the degrees of latitude decrease from the equator to the poles, it shows that the earth is prolate, but if they increase from the equator toward the poles it is a proof that it is oblate in shape.

Let us now go back to the year 1687, the date of the publication of Newton's Principia. In Book III of that great work are discussed the observations of Richer, who, having been sent to Cayennne, in equatorial South America, on an astronomical expedition, noted that his clock, which kept accurate time in Paris, there continually lost two seconds daily, and could only be corrected by shortening the pendulum. Now, the time of oscillation of a pendulum of constant length depends upon the force of gravity, and Newton showed, after making due allowance for the effect of centrifugal force, that the force of gravity at Cayenne, compared with that at Paris, was too small for the hypothesis of a spherical globe; in short, that Cayenne was further from the center of the globe than Paris, or that the earth was an oblate spheroid, flattened at the poles. He computed, too, that the amount of this flattening at both poles was between $\frac{1}{180}$ and $\frac{1}{300}$ of the whole diameter. Now, you will remember that Newton's philosophy did not gain ready acceptance in France; this investigation, in particular, called forth much argument, and when Cassini's surveys were completed, indicating a prolate spheroid, the discussion became a controversy. Then the French Academy resolved to send out two expeditions to make measurements of meridian arcs that would definitely settle the matter, one to the equator and another as far north as possible; for it was evident that observations near the latitude of France could afford but little information concerning the ellipticity of the meridian. Accordingly two parties sailed in 1735—Maupertius to Lapland, and Bouguer and Lacondamine to Peru. Maupertius measured his base upon the frozen surface of the river Tornea, executed his triangulation and latitude observations and returned to France in less than two years. The Peruvian expedition, whose work we have already described, was absent about seven years, but upon its return the following results could be written:

Arc.	Mean lat.	1° in toises.
Lapland ..	N 66° 20′	57438
France ...	N 49° 22′	57060
Peru	S 1° 34′	56728

These figures decided the question; from this time on, every one has granted that the earth is an oblate spheroid, rather than a sphere or a prolate spheroid.

Our consideration of the earth as a sphere is not yet finished, and it cannot be here completed without anticipating to a certain extent some of the results of the following lectures. What has already been said is sufficient for us to observe that the amount of flattening at the poles, and the deviation from the spherical form is not large. In fact, on a globe sixteen inches in equatorial diameter, and on which the thickness of a coat of varnish would represent the elevation of the lands above the waters, the polar axis would be 15.945 inches, or in other words, the difference between the polar and equatorial diameters would be but one-eighteenth of an inch. It is hence evident that for many purposes it is sufficiently accurate to consider the earth as a sphere. What value then shall we take for its radius, and what is the mean length of a degree of latitude on its surface?

The mean length of a degree of latitude is the average of the lengths of all the degrees from the equator to the poles, or one-ninetieth of the elliptical quadrant. Now the following are some of the values of the length of the quadrant, according to the calculations of mathematicians, made by methods which we shall endeavor to speak of in the next lecture:

Year.	By whom.	Quadrant in Meters.
1806	Delambre	10 000 000
1819	Walbeck	10 000 268
1830	Schmidt	10 000 075
1831	Airy	10 000 976
1841	Bessel	10 000 856
1856	Clarke	10 001 515
1863	Pratt	10 001 924
1866	Clarke	10 001 887
1868	Fischer	10 001 714
1872	Listing	10 000 218
1873	Clarke	10 001 472 max. 10 000 425 min.
1878	Jordan	10 000 681

It will be seen from this table that scientists are by no means yet able to agree upon the length of the quadrant to single meters, or tens or hundreds of meters. We select the value of Bessel, 10 000 856 meters, for two reasons, first and mainly, because this and the other dimensions of the spheroid as deduced by Bessel have been long in use in geodetic computations, and are now still in use, notwithstanding all the later investigations; and, secondly, because in regarding the earth as a sphere, it makes little difference in our results whichever value be taken (and the average of the above thirteen values is 10 000 894 meters, or nearer to Bessel's value than to any other). The mean length of one degree is then

$$\frac{10\,000\,856}{90}=111\,121 \text{ meters.}$$

From this is deduced the following useful table of mean length of arcs of latitude:

Length of	In Meters.	In Feet.
One degree	111 121	364 556
One minute	1852	6 076
One second	30.9	101.3

The mean length of one degree in statute miles is 69.043 or $69\frac{1}{22}$. As the probable error of Bessel's value of the quadrant is about 500 meters, the probable error of the above mean length of one degree is about 55 meters or 180 feet. Stated in round numbers, easy to remember, the result is:

1° of latitude = 111.1 kilometers = 69 miles.

The mean radius of the earth, considered as a sphere, can be nothing more than the arithmetical mean or average of all the radii of the spheroid. A moment's reflection will convince us that this mean radius is the same as the radius of a sphere having a volume equal to the volume of the spheroid. Let a be the equatorial and b be the polar radius of the oblate spheroid, equal, according to Bessel to 6 377 397 and 6 356 079 meters respectively; the volume is $\frac{4}{3}\pi a^2 b$. Let r be the radius of the sphere whose volume is $\frac{4}{3}\pi r^3$. Place these values equal and we have

$$r=\sqrt[3]{a^2 b}$$

which gives

$$r=6\,370\,283 \text{ meters,}$$

or in round numbers

$$r=6370 \text{ kilometers,}$$

$$r=20899 \text{ thousand feet,}$$

$$r=3958 \text{ statute miles}$$

for the mean radius of the waters of the earth.

This mean value of r is, however, incongruous with the above mean length of a degree of latitude, since the quadrant corresponding to a radius of 6370 kilometers is nearly 6 kilometers greater than Bessel's elliptical quadrant of 10000856 meters. In some kinds of map projections it may be more logical to use the radius of a circle whose circumference is equal to the circumference of the meridian ellipse; this requires the equation

$$\tfrac{1}{2}\pi r=10000856 \text{ meters,}$$

from which

$$r=6366743 \text{ meters,}$$

or in round numbers

$$r=6367 \text{ kilometers}=3956 \text{ miles,}$$

which is less by two miles than the mean radius of the sphere. This discrepancy is unavoidable, since the properties of a sphere and an ellipsoid are not the same. At the beginning of our discussion we saw that the earth's suface could not be plane because of the discrepancies of surveys with the geometry of the plane, and here we see that it is also impossible, when precision is required, to consider it as spherical. Therefore, whenever in any problem, a variation of two or three miles in the length of the mean radius would make any practical change in the result of the solution it is better to regard the earth as an oblate spheroid—and this we shall discuss in the next lecture.

STEAM BOILER FURNACES FOR SMOKE PREVENTION.

By JOHN W. HILL, M. E.

Written for VAN NOSTRAND'S MAGAZINE.

The Board of Commissioners of the Cincinnati Industrial Exposition (1879) offered a cash premium of *five hundred dollars* for the best furnace system for steam boiler use, designed to burn bituminous coal without smoke.

All competing devices to be submitted to expert trials, and, to be durable, practical and capable of ready application to the prevailing types of steam boilers.

Five entries were made for the trials, as follows: The Walker Twin Furnace, by R. L. Walker & Co., of Boston, Mass: this furnace formed part of the setting of an ordinary return tubular boiler at the dry goods house of John Shillito & Co. The Fisher furnaces, by Lawrence Foulds & Fisher, of Cincinnati; this furnace formed part of the setting of a return tubular boiler at the printing establishment of Strobridge & Co.

The Eureka furnace attachment, by Douglass, Ludlow & Hart, of Cincinnati; this device was connected with the setting of a battery of two return tubular boilers at the Lane & Bodley Co. machine shops.

The Price furnace, by Wm. Price, of Cincinnati; this furnace formed part of the setting of a return tubular boiler at the Price hill inclined plane.

The Murphy furnace, by Thomas Murphy, of Detroit, Michigan; this furnace was built specially for the trials, and was set with an independent boiler on the direct and drop flue plan.

The connected boilers of all the furnaces, excepting the Murphy, furnished steam for the daily requirements of the several establishments where they were located. The steam from the Murphy boiler was blown into the atmosphere, and wasted.

THE WALKER TWIN FURNACE.

This furnace consists essentially of two independent grates, located in separate fire chambers, at opposite ends of the boiler. A pair of dampers—one at each end of the setting so arranged, that when one is closed the other is opened, and vice versa—control the direction given the gases of combustion in transit to the chimney.

The grates are alternately charged with coal, the gases of quick evolution from the freshly charged coal passing through two perforated bridge walls, and over the bed of glowing coal on the opposite grate.

The fire chamber containing the green coal, acts as a retort for the distillation of the volatile matter, which matter, as it passes through the air chamber and over the incandescent fire is oxydized and reduced to carbonic acid, or oxyd, vapor of water and sulphurous acid.

The Walker furnace at the Shillito buildings was set with a horizontal tubular boiler, furnishing steam for working the elevators, and for warming the building.

The following are the principal dimensions of furnace and boiler:

DIMENSIONS.

Boiler.	Tubular.
Length of shell	16 ft.
Diam. " "	60 ins.
Number of Tubes	48
Diam. " " (outside)	4 ins.
Heating surface shell	142.992
" " " tubes	804.249
" " " heads	16.396
" " " total	963.637
Cross section of tubes	344 sup. ft.
Furnace.	**Double.**
Length of fire chamber (each)	34 ins.
Width " " "	60 ins.
Grate surface, "	14.165
" " both,	28.33 sup. ft.
Heating to grate surface	34.015
Grate surface to cross-section of tubes	8.235

Grate surface to cross-section of chimney	2.555
Distance from grate to boiler	20 ins.
Bridge walls.	Perforated.
Chimney from surface of grate	148.33 ft.
Cross-section of chimney	11.09 sup. ft.

THE FISHER FURNACE.

In this furnace the ash pit is divided transversely by a brick wall built close up under the grate; Two-thirds of the ash pit being forward of the division wall. The grate is supposed to be divided into surfaces : a forward surface and a rear surface. The bars and air spaces of the forward surface are parallel to the axis of boiler, and inclined downwards seven inches in thirty-two. The rear grate is horizontal, with bars and air spaces transversely of axis of boiler. The bridge is vertical, and is built up to within seven and one-half inches of the bottom of boiler.

An air duct passes from front to rear through the bridge wall ; the opening in front, being directly under the rear grate, and the opening in the rear within two or three courses of the crest of the wall.

The opening in the rear of the bridge wall is covered with a perforated iron plate, through which the air is distributed in fine jets. Similarly perforated openings are provided in the side wall opposite the fire chamber, and aft of the bridge wall. The perforated plates in the side walls are fitted with slides to regulate the amount of opening, or close the perforations entirely.

The furnace was set with a well proportioned return flue boiler, furnishing steam to work the elevator and machinery in the printing establishment.

The following are the principal dimensions of furnace and boiler:

Boiler.	Flue.
Length of shell	24 ft.
Diam. " "	48 ins.
Number of flues	6
Diam. " " (outside)	2-10 in.
Diam. " "	4- 8 "
Heating surface shell	180.95
Heating surface flues	326.72
" " heads	11.78
" " total	519.45 sup. ft.
Cross-section of flues	2.212 " "
Furnace.	Single.
Length of fire chamber	50 ins.
Width " "	48 "
Grate surface	16.640 sup ft.
Heating to grate surface	31.970
Grate surface to cross-section of flues	7.523
Grate surface to cross-section of chimney	4.160
Distance from grate to boiler	17.24 ins.
Space over bridge wall	75 "
Chimney from surface of grate	58.33 ft.
Cross-section of chimney	4.00 supt. ft.

THE EUREKA FURNACE ATTACHMENT.

This device consists of a series of steam jets, surrounded by circular bell-shaped muzzles, set in the furnace front, through which air is drawn into the fire chamber by induction.

The device, as tried under a battery of two boilers, embraced eight steam nozzles, having a free orifice, .0625″ diameter and eight air nozzles, having a free orifice, 1.25″ diameter.

The steam nozzles are all connected to a horizontal pipe passing across the furnace front over the fire doors. This pipe receives steam from the boilers, the flue being regulated by an ordinary stod valve.

The furnace is unchanged in applying this attachment, except the drilling of a horizontal series of holes in the fire front for the reception of the air nozzles.

The boilers' return tubular furnished steam for the foundry and machine shop of the Lane & Bodley Co., and were set in the manner common to their class.

The following are the principal dimensions of furnace and boilers :

Boilers.	Tubular.
Length of shell	16 ft.
Diameter of shell	38 ins.
Number of tubes, (each boiler)	21
Diameter of tubes, (outside)	4
Heating surface shells	160.000
" " tubes	703.718
" " heads	16.446
" " total	880.158 sup. ft
Cross section of tubes	3.010 "
Furnace.	Single.
Length of fire chamber	48 ins.
Width " "	72 "
Grate surface	24 sup. ft.
Heating to grate surface	36.673
Grate surface to cross section of tubes	7.973
Grate surface to cross section of chimney	2.396
Distance from grate to boiler	17 ins.
Space over bridge wall	7 "
Chimney from surface of grate	57.34 ft.
Cross section of chimney	10.017 sup. ft.

THE PRICE FURNACE.

This furnace consists of two parallel fire chambers and grate surfaces, made by dividing the usual fire chamber with a longitudinal wall, built from the floor of the ash-pit, close up to the boiler. Near the forward end the wall is perforated with at throat, to form a connection between the two fire chambers. The gases of quick evolution from the green coal of one grate pass through the throat and over the incandescent coke on the opposite grate in transit through the furnace.

The division wall extends back to the bridge wall, which, in this furnace, is built close up to, and with an inverted arch embraces the bottom of the boiler.

Through the lower portion of the bridge wall are cut two flues or openings, capable of being alternately closed and opened by a sliding damper. By a proper working of the damper and charging of the coal, the two fire chambers are alternately made to act as retorts. The volatile matter from the freshly charged coal passes forward in the fire chamber, where it is distilled through the throat and back over the coke on the opposite grate.

The gases of combustion from both fire chambers pass back through the open flue in the bridge wall, thence through the furnace and tubes of the boiler in the usual manner.

The following are the principal dimensions of furnace and boiler:

Boiler.		Tubular.
Length of shell...............		16 ft.
Diameter of shell...............		54.5 ins.
Number of tubes...............		40
Diameter of tubes, outside......		4 ins.
Heating surface: Shell	136.976	
" " Tubes	670.208	
" " Heads	15.866	
" " Total		823.050 sup. ft.
Cross-section of tubes...........		2.867 "
Furnace.		Double.
Length of fire chambers (each)...		60 ins.
Width " " " ...		27 "
Grate surface, each	11.25	
" both............		22.50 sup. ft.
Heating to grate surface	36.58	"
Grate surface to cross-section of tubes	7.848	"
Grate surface to cross-section of chimney	4.282	"
Distance from grate to boiler....		23.27 ins.
Bridge wall.		Perforated.
Chimney from surface of grate..		88 ft.
Cross-section of chimney........		5.245 sup. ft.

THE MURPHY FURNACE.

This furnace consists principally of an independent oven, set forward of the boiler (after the manner of furnaces for burning spent tan from the leach), in which combustion is completed before the gases are permitted to impinge upon the heating surfaces of the boiler.

In the other furnaces the bottom of the boiler forms the roof of the fire chamber. In this furnace the roof of the fire chamber is a fire-brick arch of large radius.

The grate bars are single and set to form a V-shaped fire-bed, similar to the well-known Waddington grate. The grate is divided into two distinct surfaces on the axial line of fire chamber, each section of bars being mounted at the inner end on a revolving shaker shaft, operated from the front, for the removal of clinkers and ash.

The two sections of the grate are separated at the inner ends, about six inches, for the reception of a toothed clinker bar, the squared end of which is projected through the furnace front, and worked with a socket wrench.

Upon each side of the oven a hopper or magazine is placed for the reception of finely broken coal, which is fed on the grate by a reciprocating plunger sliding under the mouth of the hopper, and worked by a rock shaft from the front of the furnace.

All coal charged to the grate is first passed through the two hoppers, from which it is delivered in a partially coked state, and in small charges.

The sharp inclination of the grate bars precipitates nearly if not quite all the fusible and vitrifying matter in the coal upon the clinker bar, from which it is readily removed as desired by a partial rotation of the bar.

No hand stroking of the fire is necessary with this furnace; the entire manipulation of the coal, after it is charged into the magazines, being accomplished from the front, by the devices already mentioned.

The rear end of the oven terminates in a throat, through which the gases of combustion pass into the tubes of the boiler. The boiler direct tubular was set on the drop flue plan, the whole tendency of the hot gas being from above downwards.

A system of water heating tubes was connected to the under side of the boiler, into which the feed water was introduced direct from the pump, and around which the hot gas circulated just before passing into the chimney.

The following are the principal dimensions of furnace and boiler:

Boiler.	Tubular.
Length of shell	8 ft.
Diameter of shell	36 ins.
Number of fire tubes	30
Diameter " " (outside)	3 ins.
Number of water tubes	49 ins.
Length of water tubes	8 ft.
Diameter " " (inside)	1 in.
Heating surface shell 32.987	
" " fire tubes. 188.496	
" " heads... 3.686	
" " water tubes. 102.626	
" " total	327.795 sup. ft.
Cross-section of fire tubes	1.127 "

Furnace	Single.
Length of furnace	36 ins.
Width " "	42 "
Grate surface	10.50 sup. ft.
Heating to grate surface	31.22 "
Grate surface to cross-section of fire tubes	9.313 "
Great surface to cross-section of chimney	9.822 "
Chimney from surface of grate	40 ft.
Cross-section of chimney	1.069 sup. ft.

Pittsburgh coal was chosen for the trials for several reasons: First; the high percentage of volatile matter and facility with which it is distilled from the fuel renders it a difficult coal to work in furnaces designed for smoke prevention, and a furnace capable of working this coal successfully (in the matter of smoke prevention) can be relied upon to furnish equivalent if not better results with any other coal: Second; Pittsburgh coal contains a higher percentage of combustible and a higher thermal value per unit of combustible, than any other known coal; and economic results obtained from this coal exhibit the maximum efficiency of furnace, under the conditions of trial: Third; Pittsburgh coal is well-known wherever bitumenous coal is used in the United States, and the results of trials with this coal, can be easily compared with the results of many former trials reduced to a Pittsburgh coal basis.

The coal used for the trials was obtained from the yards of Marmet & Co (Cincinnati) and was of excellent quality. From the analysis for the purpose of the trials by Prof. Bruno Kniffler, and the known distribution of heat in the trial of the Murphy furnace, the thermal value of the combustible has been taken at 15500 units.

The coal was weighed to all the furnaces excepting the Murphy in uniform charges of 200 pounds.

The comparatively small dimensions of the Murphy furnace and boiler, and low actual rate of coal consumption, suggested the propriety of uniform charges of 100 pounds, in this instance.

The charges (time and weight) of coal were noted and checked independently by two observers, and no charge was permitted to be removed from the scale until both observers were satisfied as to the weight, and had entered the charge in their note books.

At the end of trial, after the fire was restored to its original condition under the direction of the writer, the unburnt coal was weighed back and deducted from the total quantity charged.

The fire and ash pit having been carefully cleaned at commencement of trial, all ash and clinker on the grate and in the ash pit at end of trial was weighed back dry, and the difference between this weight and the net weight of coal charged, is held to represent the weight of combustible fired.

Of the weight of ash and clinker returned, was a small percentage of combustible, which worked through the grate, the value of which is obtained by deducting from the observed weight of non-combustible—the weight of non-combustible, as determined by analysis.

Each competitor had complete control of his coal and furnace during the trial.

The water delivered to the boilers was measured in a tight tank divided into two compartments, one compartment containing 1728.5 pounds, and the other 1727.0 pounds with water at 70 Fahr. In the upper edge of the partition dividing the tank, a notch was cut with beveled edges. The compartments of the tank were alternately filled to the crest of the dividing partition, from the city mains, and drawn down to the lower edge of the outlet pipe in the side of the tank. Uniform volumes of water were delivered by the measuring tank for all the trials.

From either compartment of the measuring tank, the water was drawn into a supplemental tank, connected with the feed pump. The level of water in the supplemental tank being carefully noted at commencement of trial, the same level obtained at end of trial, and the number of full tanks charged together with the final partial tank, held to represent the total delivery of water to the boilers during the trial.

To determine the thermal value of the steam furnished by the boiler a small quantity was drawn through a calorimeter and condensed. The condensation was collected in a tight tin can and periodically weighed. The water expended in condensing the steam was measured into a tight barrel through a Worthington meter.

From the barrel the water entered the condenser at the bottom at a normal temperature, and passed out at the top at an elevated temperature: the elevation of temperature being due, the heat transferred from the steam to water, which was all it contained, except the small quantity resident in the condensation as it flowed from the end of the worm. The temperatures of the condensing water as it entered and left the condenser, and the temperature of the condensation as it left the worm, were read to quarter degreee regularly every fifteen minutes.

The observations of smoke issuing from the chimney were taken regularly even seven and one half minutes during the trial, except in cases when the darkness near the end of trial prevented an accurate reading of the chimney.

In reading the chimney, the following arbitrary code governed the observers.

The entire absence of smoke was taken at 100, indicating the best possible smoke-prevention. Faint traces of smoke in the waste gases was taken at 90, indicating a result sometimes obtained with an excellent construction of furnace and a skillful manipulation of the fire. Discoloration of the waste gases, readily perceptible, was taken at 75, indicating a state of smoke-prevention above the average of furnace performance. Ordinary smoke issuing from the chimney was taken at 50. Fairly black smoke was taken at 30, and thick, dense, black smoke was taken at 10.

The trials were made upon the following dates:

Walker furnace		Oct. 1st.
Fisher "		" 4th.
Eureka "	attachment	" 7th.
Price "		" 10th
Murphy "		" 14th

The trials were limited to ten hours each, by reason of all the furnaces, excepting the Murphy, being in manufacturing establishments, where night runs would have been objected to.

The duration of trials was as follows:

Walker	8:30 A. M.	to	6:30 P. M.
Fisher	8:00 "	"	6:00 "
Eureka	8:15 "	"	6:15 "
Price	8:45 "	"	6:45 "
Murphy	8:30 "	"	6:30 "

The steam pressures were read from a Bourdon gage which had been carefully prepared for the trials; and the following are means of forty-one readings:

STEAM PRESSURES.

Walker	38.755 Pds.
Fisher	80.287 "
Eureka	76.181 "
Price	82.100 "
Murphy	81.575 "

The temperature of air, water from City mains, and feed to the boiler, were taken with Green and Tagliabue thermometers: and the temperature of feed when water was heated by exhaust steam from the connected engine, was taken in the feed pipe close to the check valve. The Walker and Murphy boilers were unprovided with feed heating apparatus, and took water direct from the supplemental tank. The following are means of forty-one observations:

TEMPERATURE OF AIR.

Walker	100.07 Fahr.
Fisher	83.27 "
Eureka	82.21 "
Price	83.46 "
Murphy	80.28 "

TEMPERATURE OF WATER FROM CITY MAINS.

Walker	70.025 Fahr.
Fisher	71.069 "
Eureka	72.640 "
Price	73.569 "
Murphy	74.550 "

TEMPERATURE OF FEED.

Walker	70.025 Fahr.
Fisher	166.012 "
Eureka	169.112 "
Price	176.360 "
Murphy	74.550 "

The pressure of atmosphere was read from a compensated aneroid barometer, and the following are means of forty-one observations:

Walker	29.760	Ins.
Fisher	29.693	"
Eureka	29.630	"
Price	29.334	"
Murphy	29.156	"

The temperature of waste gases was taken with a high range centigrade thermometer. In the front connection, near the chimney, a hole was cut for the reception of an iron tube, closed at the lower end, in which the thermometer was suspended with a bath of linseed oil. With the exception of the Fisher trial, where the oil boiled over several times, the following are the means of forty-one observations:

TEMPERATURE OF WASTE GASES.

Walker	541.29	Fahr.
Fisher	542.28	"
Eureka	468.30	"
Price	423.05	"
Murphy	279.67	"

The temperatures of hot gas in the fire chamber and in the back connection were taken by calorimeter process: pieces of one inch bar iron, six inches long, were drilled axially for the introduction of a steel rod, upon which the wrought iron bar was mounted and thrust into the center of the fire chamber and back connection through apertures cut in the brick work. The iron rods were made to weigh precisely *one* pound and to fit the steel rod loosely. Into a pail ten pounds of water was carefully weighed; the iron rods, being allowed to remain in the furnace a sufficient length of time to acquire the temperature of the enveloping hot gas, they were carefully withdrawn and dropped into the pail. The known weights of iron and water and elevation of temperature of water, together with the specific heat of wrought iron, constitute the elements of the calculations. Thetempera tures of water were taken with a Green thermometer, and the specific heat of the iron rods was taken at .1139. The actual specific heat of water at observed temperatures was neglected, and the specific heat uniformly taken as 1.0000. The following are means of ten set of observations during each trial.

TEMPERATURE OF FIRE.

Walker	chamber with incandescent fire	1931.24	Fahr.
	chamber with green fire	1486.68	"
Fisher		1902.94	"
Eureka		2369.30	"
Price	chamber with incandescent fire	3053.00	"
	chamber with green fire	2491.07	"
Murphy		3056.75	"

TEMPERATURE BACK END.-

Walker	See green fire.	
Fisher	665.12	Fahr.
Eureka	1043.15	"
Price	1587.92	"
Murphy	812.35	"

To determine the amount of heat expanded in elevating the temperature of the vapor of water in the air hygrometer, readings were made half hourly during each trial, with the following results, as means of twenty-one observations.

HYGROMETER.

	Air.	Dew Point.	Dryness.
Walker	97.65	84.83	12.82
Fisher	83.82	71.54	12.28
Eureka	81.52	69.85	11.68
Price	83.34	75.15	8.19
Murphy	80.70	72.18	8.52

The calorimeter data, from which the quality of steam furnished is calculated, have been averaged for each trial, and are given in the following table;

INITIAL TEMPERATURE, CONDENSING WATER.

Walker	74.09	Fahr.
Fisher	73.94	"
Eureka	73.43	"
Price	76.40	"
Murphy	74.37	"

FINAL TEMPERATURE, CONDENSING WATER.

Walker	87.66	Fahr.
Fisher	86.14	"
Eureka	81.42	"
Price	97.22	"
Murphy	114.96	"

THERMAL UNITS PER POUND OF CONDENSING WATER.

Walker	13.57	Fahr.
Fisher	12.20	"
Eureka	7.99	"
Price	20.82	"
Murphy	40.59	"

TEMPERATURE OF CONDENSATION.

Walker	85 43	Fahr.
Fisher	83.40	"
Eureka	79.00	"
Price	85.71	"
Murphy	77.08	"

CONDENSING WATER, PER LB. OF STEAM.

Walker....	$\frac{3288.75 \text{ water}}{51 \text{ steam}}$	... 64.483 Pounds.
Fisher.....	$\frac{10041.53 \text{ water}}{139 \text{ steam}}$	... 72.240 "
Eureka....	$\frac{6633.61 \text{ water}}{57.18 \text{ steam}}$	...116.012 "
Price......	$\frac{6362.82 \text{ water}}{93.25 \text{ steam}}$	... 68.233 "
Murphy ...	$\frac{5564.70 \text{ water}}{165.56 \text{ steam}}$	... 33.611 "

The utter unreliability of boiler efficiency, based upon the water pumped into the boiler, and the coal fed on the grate, was never better shown than by these trials. None of the boilers were hard worked, and without data to the contrary, it would naturally be supposed that the low rate of evaporation per unit of heating surface, and low rate of coal consumption per unit of grate surface, would guarantee saturated steam.

In the following table the heat per pound of steam is based upon the total water fed to boiler, or rather upon the proportion of that water as evaporation diverted to the condenser. In the Walker, Fisher and Eureka boilers a material portion of the water pumped in was entrained in the steam, producing a mean thermal value per pound of steam considerably less than that of saturated steam at observed pressures. Upon the other hand, the Price and Murphy steam exhibits a very high super-heat.

TOTAL HEAT PER POUND OF STEAM CONDENSED.

Walker........................	960.46 units.
Fischer........................	964.73 "
Eureka........................	1005.93 "
Price........................	1506.32 "
Murphy........................	1441.35 "

The air entering the furnace per pound of combustible has been calculated from the known temperature of fire, thermal value of the combustible and mean specific heat of the gases of combustion.

The mean observed temperature of fire in the Walker furnace was 1931.24, and taking the mean specific heat of the gases of combustion at .238; then the weight of hot gas per pound of combustible becomes

$$\frac{15,500}{(1931.24-100.07).238} = 35.565 \text{ pounds;}$$

of this quantity one pound was combustible from the coal.

The mean observed temperature of fire in the Fisher furnace was 1902.94; and the weight of hot gas per pound of combustible

$$\frac{15,500}{(1902.94-83.27).238} = 35.789 \text{ pounds;}$$

of this quantity one pound was combustible from the coal.

The mean observed temperature of fire in the Eureka furnace was 2369.30; and weight of hot gas per pound of combustible

$$\frac{15,500}{(2369.30-82.21).238} = 28.475 \text{ pounds;}$$

of this quantity one pound was combustible from the coal.

The mean observed temperature of fire in the Price furnace was 3053.00; and weight of hot gas per pound of combustible

$$\frac{15,500}{(3053-83.46).238} = 21.931 \text{ pounds;}$$

of this quantity one pound was combustible from the coal.

The mean observed temperature of fire in the Murphy furnace was 3056.75; and weight of hot gas per pound of combustible

$$\frac{15,500}{(3056.75-80.28).238} = 21.880 \text{ pounds;}$$

of this quantity one pound was combustible from the coal.

AIR PER POUND OF COMBUSTIBLE.

Walker..................	34.565 pounds.
Fisher..................	34 789 "
Eureka..................	27.475 "
Price..................	20.931 "
Murphy..................	20.880 "

The weight of vapor of water in the air supporting combustion is stated in decimal of a pound per pound of air supplied.

VAPOR OF WATER IN THE AIR.

Walker........................	.02314
Fisher........................	.01556
Eureka........................	.01485
Price........................	.01787
Murphy........................	.01612

In the following table are given the total quantities of coal charged, ash and clinker returned, water pumped into boilers, per centage of net coal charged, utilized as combustible, and combustible in ash in per centage of net coal charged.

COAL CHARGED.

Walker	3800 pounds.
Fisher	1866 "
Eureka	3420 "
Price	2694 "
Murphy	779 "

ASH, CLINKER AND COMBUSTIBLE RETURNED.

Walker	202.00 pounds.
Fisher	87.50 "
Eureka	113.00 "
Price	119.00 "
Murphy	28.75 "

PER CENTAGE OF COMBUSTIBLE.

Walker	94.685
Fisher	95.365
Eureka	96.692
Price	95.582
Murphy	96.306

COMBUSTIBLE IN ASH.

Walker	2.273
Fisher	1.593
Eureka	0.262
Price	1.376
Murphy	0.652

WATER TO BOILERS.

Walker	28859.00 pounds.
Fisher	10896.00 "
Eureka	33133.77 "
Price	23282.92 "
Murphy	6854.50 "

EVAPORATION.

The apparent evaporation per pound of coal with the Walker furnace and boiler was $\frac{28859}{3800} = 7.5946$ pounds; but the mean heat per pound of steam condensed in the calorimeter was 960.46 units, and total heat per pound of coal in the steam was $7.5945 \times 960.46 = 7294.21$ units. Of this quantity $70.025 \times 7.5945 = 513.8$ units were in the feed water, and the evaporation per pound of coal from and at a temperature of 212 Fahr., becomes

$$\frac{7294.21 - 513.8}{966} = 7.019 \text{ pounds.}$$

The combustible was .94685 of net coal charged and evaporation per pound of combustible, from and at 212 Fahr. was,

$$\frac{7.019}{.94685} = 7.413 \text{ pounds.}$$

The apparent evaporation per pound of coal with the Fisher furnace and boiler was $\frac{10896}{1866} = 5.839$ pounds; but the mean heat per pound of steam condensed in the calorimeter was 964.73 units, and total heat per pound of coal in the steam was

$$5.839 \times 964.73 = 5633.058 \text{ units.}$$

Of this quantity

$$166.012 \times 5.839 = 969.34 \text{ units}$$

were in the feed water, and the evaporation per pound of coal from and at a temperature of 212 Fahr. was,

$$\frac{5633.058 - 969.34}{966} = 4.828 \text{ pounds.}$$

The combustible was .95365 of net coal charged and evaporation per pound of combustible, from and at 212 Fahr. was,

$$\frac{4.828}{.95365} = 5.062 \text{ pounds.}$$

The apparent evaporation per pound of coal with the Eureka furnace and boiler was $\frac{33133.77}{3420} = 9.688$ pounds; but the mean heat per pound of steam condensed in the calorimeter was 1005.93 units, and total heat per pound of coal in the steam was

$$1005.93 \times 9.688 = 9745.45 \text{ units.}$$

Of this quantity, $169.112 \times 9.688 = 1638.357$ units were in the feed water, and evaporation per pound of coal from and at 212 Fahr., was

$$\frac{9745.45 - 1638.357}{966} = 8.392 \text{ pounds.}$$

The evaporation by the Eureka boiler should be reduced by the amount of steam eqpended in maintaining the jets. The orifices in the nozzles were .0625″ diameter, and area of eight nozzles

$$\frac{8. \times 0625^2 \times .7854}{144} = .00017 \text{ sup. ft.}$$

Considering the form of the nozzle, and approach thereto, it is probable that the velocity of flow referred to full area of orifice, was about 1,000 feet per second, from which is obtained the weight of steam expended per hour in the jets, as

$$3600 \times .00017 \times 1000 \times .2139 = 131.33 \text{ pounds,}$$

and per centage of steam absorbed by the device.

$$\frac{131.33}{2545.}=.0516^*$$

From which is deduced the net evaporation per pound of coal from, and at 212 Fahr., as

$$.9484 \times 8.392=7.957 \text{ pounds.}$$

The combustible was .96692 of net coal charged, and evaporation per pound of combustible from and at 212 Fahr., was

$$\frac{7.959}{.96692}=8.231 \text{ pounds.}$$

The apparent evaporation per pound of coal with the Price furnace and boiler was

$$\frac{23282.92}{2694}=8.6425 \text{ pounds;}$$

but the mean heat per pound of steam condensed in the calorimeter, was 1506.32 units, and total heat per pound of coal in the steam was

$$1506.32 \times 8.6425=13018.37 \text{ units.}$$

Of this quantity,

$$176.36 \times 8.6425=1524.17 \text{ units}$$

were in the feed water, and the evaporation per pound of coal from and at 212 Fahr., was

$$\frac{13018.37-1524.17}{966}=11.8988 \text{ pounds.}$$

The combustible was .95582 of net coal charged, and evaporation per pound of combustible from and at 212 Fahr., was

$$\frac{11.8988}{.95582}=12.449 \text{ pounds,}$$

The apparent evaporation per pound of coal with the Murphy furnace and boiler was

$$\frac{6854.5}{779}=8.7991 \text{ pounds.}$$

but the mean heat per pound of steam condensed in the calorimeter was 1441.35 units, and total heat per pound of coal was

$$1441.35+8.7991=12.682.58 \text{ units.}$$

Of this quantity,

$$74.55+8.7991=655.973 \text{ units}$$

were in the feed-water, and the evaporation per pound of coal from and at 212 Fahr., was

$$\frac{12682.58-655.973}{966}=12.4499 \text{ pounds.}$$

The combustible was .96306 of net coal charged, and evaporation per pound of combustible from and at 212 Fahr., was

$$\frac{12.4499}{.96306}=12.9274 \text{ pounds.}$$

CAPACITY OF BOILER.

The rate of evaporation per superficial foot of heating surface per hour, from and at 212 Fahr. was for the Walker boiler,

$$\frac{7.019 \times 380}{963.637}=2.7679 \text{ pounds.}$$

For the Fisher boiler,

$$\frac{4.828 \times 186.6}{519.45}=1.7343 \text{ pounds.}$$

For the Eureka boiler

$$\frac{7.959 \times 342}{880.158}=3.2062 \text{ pounds.}$$

For the Price boiler,

$$\frac{11.8988 \times 269.4}{823.05}=3.8947 \text{ pounds.}$$

For the Murphy boiler,

$$\frac{12.4499 \times 77.9}{327.795}=2.9587 \text{ pounds.}$$

RATE OF COMBUSTION.

The coal charged per superficial foot of grate, per hour, was for the Walker furnace,

$$\frac{380}{28.33}=13.413 \text{ pounds.}$$

For the Fisher furnace,

$$\frac{186.6}{16.64}=11.214 \text{ pounds.}$$

For the Eureka furnace,

$$\frac{342}{24}=14.25 \text{ pounds.}$$

For the Price furnace.

* In the report of this trial to the Commissioners of the Exposition, an error occurs in stating the fraction of total steam expending in maintaining the jets. The calculation resulting in 131.33 pounds, supposes steam *only* to pass the orifices. The error lay in overlooking the fact that the percentage of water entrained in the steam, passed through the calorimeter, would also apply to the steam passed by the jets. In other words, the denominator of the fraction representing the steam expended in maintaining the jets should have been the net evaporation per hour instead of the water per hour pumped into the boilers. The water entrained (23.19 per cent.) had a relative volume of $291.66.\frac{.7681}{2319}=965$ or 1 per cent. of the volume of steam discharged.

$$\frac{269.4}{22.50}=11.973 \text{ pounds.}$$

For the Murphy furnace,

$$\frac{77.9}{10.5}=7.419 \text{ pounds.}$$

RESUME OF RESULTS.

Steam per pound of coal from and at 212 Fahr.

Walker	7.019 pounds.
Fisher	4.828 "
Eureka	7.959 "
Price	11.898 "
Murphy	12.450 "

Steam per pound of combustible from and at 212 Fahr.

Walker	7.413 pounds.
Fisher	5.062 "
Eureka	8.231 "
Price	12.449 "
Murphy	12.927 "

Steam per sup.-foot of heating surface per hour.

Walker	2.7679 pounds.
Fisher	1.7343 "
Enreka	3.2062 "
Price	3.8947 "
Murphy	2.9587 "

Coal per sup.-foot of grate surface per hour.

Walker	13.413 pounds.
Fisher	11.214 "
Eureka	14.250 "
Price	11.973 "
Murphy	7.419 "

SMOKE PREVENTION.

In comparing results in the following table it should be observed, that absolutely no smoke was rated 100, and the ordinary condition of chimney gases was taken at 50:

Walker	86.923
Fisher	80.125
Eureka	86.140
Price	81.202
Murphy	98.467

THE DISTRIBUTION OF HEAT.

Specimen lumps of coal were taken from the several lots furnished the competitors in the trials, and submitted to analysis by Prof. Bruno Kniffler, with the following result:

Fixed carbon	61.038
Volatile matter	32.750
Sulphur	0.863
Moisture	2.307
Ash	3.042
	100.000

As already stated, the thermal value of the combustible has been taken at 15,500 units: equivalent to an evaporation from and at 212 Fahr. of 16.045 pounds.

WALKER FURNACE.

	Thermal units.	Steam.	Per centage.
Steam	7161.155	7.413	46 201
Chimney gas	3734.725	3.866	24.095
Vapor of water	169.415	0.175	1.093
Moisture in coal	30.070	0.031	0 194
Combustible gas	775 000	0.802	5.000
Radiation	3629.635	3.758	23.417
	15500.000	16.045	100.000

FISHER FURNACE.

	Thermal units.	Steam.	Per centage.
Steam	4889.940	5.062	31.548
Chimney gas*	7710.320	7.982	49.744
Vapor of water	238.700	0.247	1.540
Moisture in coal	30.225	0.031	0.195
Combustible gas	1085.000	1.123	7.000
Radiation	1545.815	1.600	9.973
	155000.000	16.045	100.000

EUREKA FURNACE.

	Thermal units.	Steam.	Per centage.
Steam	8384 570	8.679	54.094
Chimney gas	2616.555	2.709	16.881
Vapor of water	75.640	0.078	0.488
Moisture in coal	28.985	0.030	0.187
Combustible gas	620.000	0.642	4.000
Radiation	3774.250	3.907	24 350
	15500.000	160.45	100.000

PRICE FURNACE.

	Thermal units.	Steam.	Per centage.
Steam	12026.140	12.449	77.588
Chimney gas	1772.890	1.835	11.438
Vapor of water	60.295	0.063	0.389
Moisture in coal	28.830	0.030	0.186
Combustible gas	387.500	0.401	2.500
Radiation	1224.345	1.267	7.899
	15500.000	16.045	100.000

MURPHY FURNACE.

	Thermal units.	Steam.	Per centage.
Steam	12488.195	12.927	80.569
Chimney gas	1033.075	1.069	6.665
Vapor of water	32.085	0 034	0.207
Moisture in coal	26.970	0.028	0.174
Combustible gas	387.500	0.401	2.500
Radiation	1532.175	1.586	9.885
	15500.000	16.045	100.000

In the tables above the first four quan-

* The air openings in the bridge wall, and in the side walls of the Fisher furnace, behind the bridge wall, are equal to the effective area of openings in front of the bridge wall, and the weight of hot gas per pound of combustible passing up the chimney was twice the weight of air per pound of combustible, plus one.

tities are calculated from known data. No analysis having been made in either of the trials, of the chimney gases; the percentage, or thermal value per pound of combustible of the combustible gas lost in the chimney is not known.

A careful comparison of the data, with that of previous trials when the chimney gases have been analyzed, suggests the values given to the combustible gas in the tables; and the heat lost by conduction and radiation is taken as the difference between the heat accounted for and the total heat of combustion.

EXPERIMENTS ON THE FILTRATION OF WATER.

By GEORGE HIGGIN, M. Inst. C. E.

From the Proceedings of the Institution of Civil Engineers.

In the autumn of the year 1877, the author, being in Buenos Ayres, had occasion to make some experiments on the filtration of the water with which it was proposed to supply that city. The works for that purpose have been designed by, and are being executed under the direction of Mr. J. F. Bateman, President Inst. C. E., the water being drawn from a deep channel of the River Plate almost in front of the town or suburb of Belgrano, and at a point about four miles above the most northerly extremity of the city.

The River Plate is formed by the junction of the rivers Paraná and Uruguay, about twenty miles above the city of Buenos Ayres. The united streams, from this point down to where they discharge into the ocean at Monte Video, bear the name of Rio de la Plata, or Silver river, translated by English people into River Plate. The total length of the River Plate is only about 120 miles; but it has a width at its mouth of 60 miles, whilst at Buenos Ayres, 100 miles from its mouth, it has a width of 30 miles. It is extremely shallow; the deep water channel seldom exceeding 22 or 24 feet in depth, whilst on the banks, which are numerous and of great extent, the depth is much less.

As stated by Mr. Bateman, in his report on the proposed "Improved Harbor Accommodation" of Buenos Ayres, 1871, the mean low-water discharge of the River Uruguay may be taken at 150,000 cubic feet per second, and that of the Paraná at 520,000 cubic feet per second. The mean low water discharge of the River Plate would be, therefore, 670,000 cubic feet per second. The water of the Uruguay is, under ordinary circumstances, clear, free from detritus, and of a good class. A sample, from the center of the river in front of Fray Bentos, on the 9th of September, 1877, when the river was high, gave, under analysis, the following result:

	Parts per Million.
Total solid residue.....	86.00
Chlorine...............	1.70
Free ammonia..........	0.03
Albumenoid ammonia...	0.20

Hardness, 1.4° per 100,000.

This water was almost clear, and threw down a very slight deposit when left in repose. Another sample, from the middle of the river in front of Higueritas, a little lower down, taken on the following day, gave, under analysis, the following result:

	Parts per Million.
Total solid residue.....	87.00
Chlorine..............	2.00
Free ammonia.........	0.00
Albumenoid ammonia..	0.14

A sample taken from the center of the river in front of the town of Concordia, and about 250 miles above its junction with the Paraná, contained only thirty-nine parts per million of total solids, and was therefore much purer than the water at Fray Bentos and Higueritas. The composition of this water was, however, curious, for out of the thirty-nine parts no less than 18.5 were composed of silicic acid, and the water contained no chlorine. Probably no other river water in the world contains such a large percentage of silicic acid, and is so free from chlorides.

The water of the Paraná is very different in composition from that of the Uruguay. The Paraná is a delta-forming river; its waters are always, even in the driest season, highly colored and opaque. In dry seasons the detritus in suspension is in so finely divided a state, that months of repose will not render the water clear, nor can it be cleared by passing through several folds of filter paper. In the wet season, or when the river comes down charged with the waters from the tropical rains of the interior, it is very turbid.

Mr. Bateman states, that at the time of his examination of the river Paraná in the autumn of 1871, "the total quantity of matter held in suspension...... was but $\frac{1}{9000}$ part by weight;" and that "this amount, will be, no doubt, increased in floods." Some experiments by the author in 1877, on the water of the River Plate, in front of Buenos Ayres, showed that it then contained $\frac{1}{1152}$ part by weight of suspended matter. The river was probably at that time in a more turbid condition than when examined by Mr. Bateman in 1871, though it could not be called "in flood." Assuming a mean flow of 700,000 cubic feet per second, which is a little more than its minimum volume, the river at that time was carrying seawards, every twenty-four hours in round numbers, 224,000 tons of sediment, or about 82,000,000 tons per annum—an enormous mass of material, which fully accounts for the deltaic character of the River Plate.

The Paraná, down to the town of San Pedro, which lies about seventy miles above its discharge into the Plate, continues in one stream. At this point it splits into two main channels; one of which, known as the Paraná de las Palmas, continues a nearly straight course down to its mouth, about twenty miles above Buenos Ayres; whilst the other, known as the Paraná Guazu, trends off in a northerly direction, and flows into the Plate in two channels, almost at the same point where the Uruguay unites with it. The triangle, formed between the town of San Pedro at the apex and the points of discharge of these two principal channels some twenty miles apart, is a delta intersected by various branches of the main streams, which wind about and cross each other in a most intricate manner. The water which flows past Buenos Ayres is probably almost entirely that coming down the Palmas branch of the Paraná.

Two comparatively small rivers, the Lujan and Tigre, join the River Plate about eighteen miles above Buenos Ayres; and although their volume is small in proportion to the Palmas branch of the Paraná, from their position on the right bank, and discharging so near the town, they probably influence the character of the water at Buenos Ayres.

According to analysis made in 1872 by Professor Kyle, of the National College of Buenos Ayres, the water of the Palmas at four leagues from its mouth, contained:

	Parts per Million.
Total solid residue.....	100.00
Chlorine..............	15.00
Free ammmonia.......	0.16
Albumenoid ammonia..	0.24

Hardness, 3.4°.

The water of the Lujan, according to an analysis, by the author, of a sample taken on the 4th of October, 1877, yielded:

	Parts per Million.
Total sold residue......	1,071.00
Chlorine................	160.50
Free ammonia.........	0 014
Albumenoid ammonia..	0.28

Hardness, 15.75°.

The water of the Tigre, according to a sample taken on the same date, and analyzed by the author, contained:

	Parts per Million.
Total solid residue......	898.76
Chlorine...............	99.90
Free ammonia..........	Traces
Albumenoid ammonia..	0.11

Hardness, 12°.

The water in front of the town of Buenos Ayres, in April 1872, contained, according to Professor Kyle:

	Parts per Million.
Total solid matter......	180.00
Chlorine....	24.00
Free ammonia.........	0.07
Albumenoid ammonia..	0.34

Hardness, 4.5°.

In front of Belgrano, whence the new supply is to be drawn, the water contained on the 12th of April, 1872, according to the same authority:

	Parts per Million.
Total solid matter......	130.00
Chlorine................	17.00
Free ammonia..........	0.06
Albumenoid ammonia..	0.24

Hardness, 4.25°.

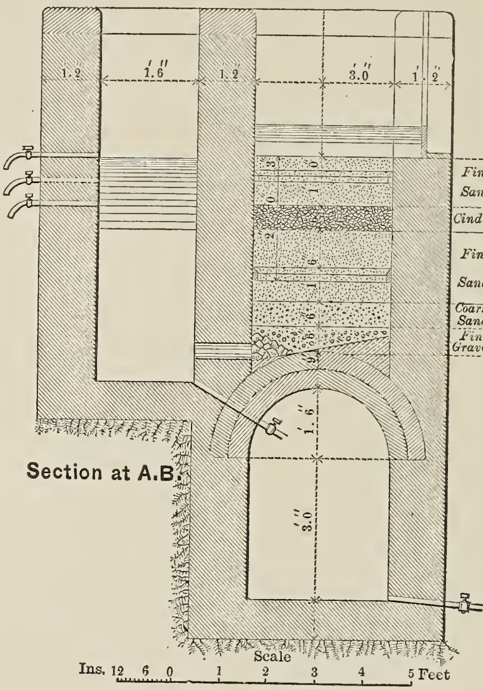
The quality of the water experimented on by the author varied almost daily, according to the changeable state of the river. The following, which is an analysis of a sample taken on the 3d of September, 1877, represents its average quality before filtration :

	Parts per Million.
Total solid residue......	357.00
Chlorine...............	39.00
Free ammonia..........	0.026
Albumenoid ammonia...	0 230

Hardness, 6.4°.

This water, in its best condition, was dirty looking and yellowish. Left in a stoppered bottle, for months together, in perfect repose, it never became clear, always remaining yellowish and opalescent. The matter in suspension appeared to be finely comminuted clay, almost in a colloid or gluey form, and incapable of mechanical precipitation in any reasonable time. Only by the addition of alum or one of the persalts of iron did it seem possible to effect a precipitation of it. The finest filter paper, even in double or triple folds, was powerless to separate the impurity. The problem for solution was, to find some material that would effect a mechanical separation of the matter in suspension, as it was not considered advisable on many grounds to have recourse to chemical precipitation.

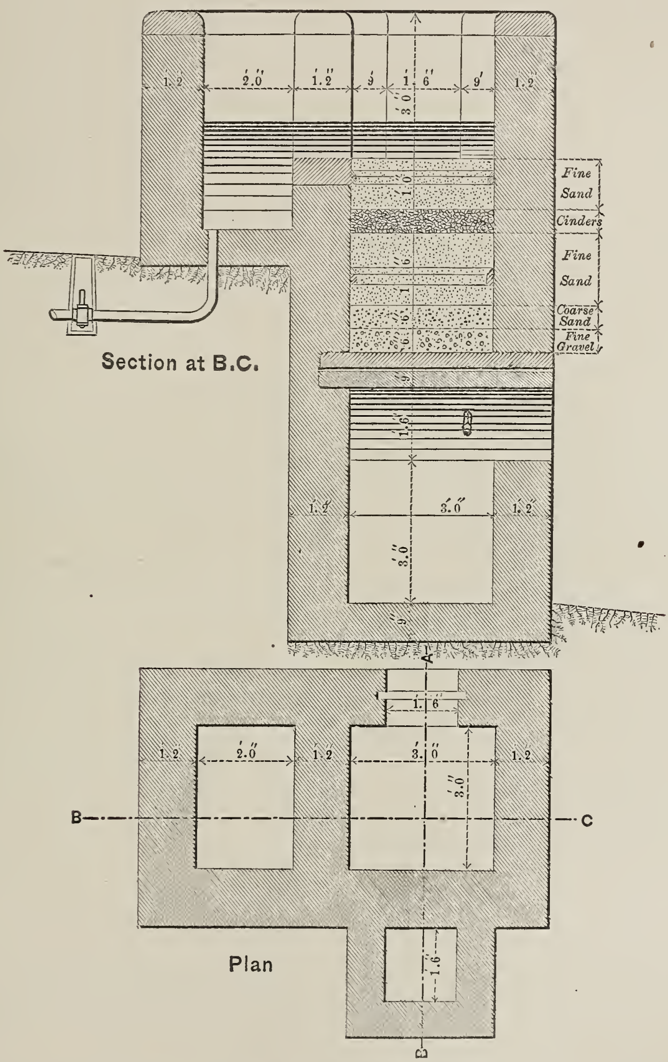
A small experimental filter was therefore constructed for the purpose (Figs. 1 and 2).



Section at A.B.

The area of the filter bed was one square yard; its depth, from the surface of the sand to the top of the arch, being four feet. Underneath the filter bed a chamber was constructed of the same area as the filter bed, and capable of containing one cubic yard of water. A small side chamber on the level of the filter bed, served for the admission of the water to be filtered. A pipe three inches in diameter was brought from the settling pools through the bottom of this chamber, and a valve on the pipe regulated the supply. The water, rising in the side chamber, flowed quietly over the surface of the filter without disturbing it. The height of the water was regulated by an opening in the side, which was provided with grooves to receive a stop plank of any desired height.

The water, after percolating the filtering material and reaching the bottom, passed through an opening into a small chamber, eighteen inches square. At the upper part of this chamber a series of pipes and cocks was inserted, the highest pipe being at the same level as the surface of the filter, the others at intervals of three inches downwards. A pipe that could be attached to any of the cocks served to convey the water from this chamber to that for measuring underneath the filter. A discharge pipe from the bottom of the effluent chamber allowed the application of an unlimited head if desirable, and provided for the emptying of the filter; while another discharge pipe permitted the cleansing of the measuring chamber. The depth



of water in the measuring chamber was taken by a small graduated rod, introduced through the opening in front. The variations of head were obtained by opening or shutting the different cocks in the effluent chamber; or where a variation was required more minute than could be given by the cocks, it was effected by varying the height of the stop-plank in the filter chamber. This stop-plank, which served as an over-flow, ensured a regular height of water in the filter chamber.

The depth of water on the filter in the

present experiments in no case exceeded twelve inches, and was frequently less. The head given in the tables is the difference of level between the water in the filter chamber and the effluent water, which is the true head. In some treatises on water, confusion is created by speaking of the head of water on a filter as though it were the depth of water on the filter bed. The depth of water on the bed is of course one element in the question, but it has by itself no relative importance; it may be three inches or three feet without the head being in any way varied. By an unlimited head, as used in the tables, is meant that given by a free exit of the water from the bottom of the filter, when the only impediment to the discharge of the water is caused by the friction of the materials through which it passes.

The principal object sought at the commencement of the experiments was to ascertain the best material to use in the large filters then approaching completion, with a view to remove, if possible, the turbid yellow appearance from the water. For this purpose the disposition and quality of the materials were varied as the experiments proceeded. At the same time, experiments were carried on in the house, the instrument used being a small copper cylinder six inches in diameter and eighteen inches high, provided with a peforated plate at the bottom, and a stopcock, to which an india-rubber tube was applied. By varying the position of this tube any desirable head could be obtained.

The experiments on the large model filter showed some curious results as regarded the rate of filtration, which the author thinks worthy of attention. The materials first employed were those commonly used in England, viz: a layer of two feet of fine sand, nine inches of coarse sand, six inches of fine gravel, six inches of coarse gravel, and three inches of rubble. The rubble was packed by hand; the sand and gravel were gently pounded. The sand was brought from the coast of Uruguay, on the opposite side of the river to Buenos Ayres. It is a sharp clean sand, being everything that could be desired. The filter was started with the lower cock open, or say with an unlimited head. The discharge of water per square yard per day was a follows:

	Gallons.
1st day	9,323
2nd "	6,552
3rd "	3,309
4th "	1,524
5th "	220
6th "	39

The water that came from the filter was not satisfactory on any of these days. It was a little better on the sixth day, but was still quite turbid, and only slightly improved as regarded its other qualities. A deposit of fine mud, about $\frac{1}{16}$ inch in thickness, covered the top of the filter. This could be torn off like a piece of cloth, leaving the sand below perfectly clean. About $\frac{1}{4}$ inch of sand was removed from the filter, and it was started again with the same head. The discharge per square yard was then:

	Gallons.
1st day	2,994
2nd "	2,706
3rd "	1,707
4th "	60

Another $\frac{1}{4}$ inch of sand was now removed, and the filtration was resumed:

	Gallons.
1st day	2,081
2nd "	1,381
3rd "	1,334
4th "	1,278

The water during all this time continued of the same unsatisfactory character.

In order to reduce the speed the head was now altered to two feet, when the filter discharged:

	Gallons.
1st day	983
2nd "	1,108
3rd "	—
4th "	1,245
5th "	1,684
6th "	2,055

This rate being too great, the head was altered to one foot six inches, when the water ran:

	Gallons.
1st day	1,303
2nd "	2,185
3rd "	3,728

The filtered water was still very turbid and only slightly improved.

The extraordinary and rapid increase in the daily speed of filtration was so different to what had been expected, and so inexplicable, that it was supposed some passage must have been opened through the sand. In order to satisfy himself on this point the author carefully removed the material, but found everything in order; the different layers had not intermingled, nor was there the slightest sign of any hole or passage through them.

The filter was, therefore, carefully remade, the same materials being used, and was started with a head of 2 feet, and gave the following result:

	Gallons.
1st day	1,059
2d "	2,348
3d "	3,729

The filter was then stopped for a day to put in some additional valves, and it was started again with a head of 12 inches. Under this head no water passed through, the water in the effluent chamber never rising to the necessary level. After leaving it for nearly a day in this position, the head was increased to 1 foot 6 inches, when the water immediately began to flow, and ran that day to the extent of 1,187 gallons; the next day the rate increased to 2,150 gallons; and as it showed the same tendency as before to a steady increase the head was changed to 1 foot, when it dropped to 711 gallons.

Thinking that the limited size of the filter, and the large proportionate area of the sides to that of the total area, might have some effect on the result obtained, by creating passages down the sides of the walls, the filter was emptied, and fillets of wood 1½ inch wide were firmly wedged up to the sides, at distances of 3 inches, and 2 feet from the surface of the sand. The upper parts or these fillets were weathered with pure cement, so as completely to prevent any flow of water down the sides.

In the former experiments the bottom cock had been left open when the filter was started, so that any air in the materials might be driven down by the water and pass out freely. Now, however, a 2-inch pipe was inserted in one angle, reaching down to the rubble, and the filter was then carefully remade, with the same material as before. It was now started with a head of 1 foot 6 inches. Its rate was, on the first day, 683 gallons; on the second day it rose to 1,602 gallons, when the head was altered to 1 foot; it then dropped to 817 gallons. The next day it was 1,479 gallons, and the following day 1,850. Without any apparent reason it then fell to 1,084 gallons, but rose on the next day to 1,400 gallons. From a scarcity of pressure in the settling pools, the head on the following day was only six inches, when the rate fell to 371 gallons. With the former head of one foot it rose again the succeeding day to 1,456 gallons; on the ninth day it was 1,220 gallons; on the tenth day, with eleven inches head, it was only 441 gallons; and on the eleventh day, with a 12-inch head, 734 gallons. The character of the filtered water during this time was still unsatisfactory, being yellowish and dirty; and from an analysis of the water filtered on August 4th, the qualities were otherwise found to be but slightly improved.

In the meanwhile, the experiments conducted in the house had led the author to the conclusion, that the object sought might be attained by the use of some other material in the filter bed. The topmost layer of sand was therefore taken out for a depth of one foot three inches, and replaced with a layer 4½ inches thick of picked and washed cinders, about the size of hazel nuts, below, with 10½ inches of fine sand on the top. With a head of six inches the filter then ran at the rate of 826 gallons for the first day, and 924 gallons for the second; but the quality of the water being still unsatisfactory, the top layer for two feet was removed, and (the lower portion of the filter remaining the same) was replaced with three inches of fine sand, one inch of coarse cinders, one foot two inches of pounded cinders (the fine dust having been washed away previously), and finally, as a top layer, six inches of fine sand. It was necessary to make the top layer of sand, as otherwise the cinders, being very light, floated up when water was admitted. The filter was then started with six inches head, and allowed the water to pass on the first day at a rate of 780 gallons, and on the second day 692 gallons. As the rate appeared to be diminishing rapidly the head was increased to nine inches, when the water percolated at the following rates:

	Gallons.
3rd day	1,156
4th "	1,335
5th "	1,502

The head was, therefore, altered back to six inches, when the flow per square yard was:

	Gallons.
5th day	881
6th "	880
7th "	827
8th "	784
9th "	763
10th "	643
11th "	468
12th "	391

This was the first occasion on which the filter had run approximately at the rate it was desired to establish, which was 700 gallons per square yard per twenty-four hours. The character of the water was now much superior. It had lost the yellow tinge; and although still of a milky look, it was considerably improved as regarded its other qualities.

The house experiments having shown that it was not desirable to remove the fine dust from the cinders, and that better results could be obtained by simply using the cinders as they came from the engines, the surface of the filter also commencing to show signs of dirt, it was determined to remake the filter, using in place of the pounded cinders those from the engine heaps, the coarser cinders being riddled out, so that none remained larger than a hazel nut. At the same time the author considered it desirable to ascertain whether there was any tendency in the different layers to run together, and therefore carefully examined them one by one as the filtering materials were removed. The examination showed that there was no tendency to run together; and as it was desirable to get a great depth of upper material for the purposes of varying them as much as possible, the lower part of the filter was altered as follows: the portion of the filter round the exit-hole was packed with small rubble, and a layer of fine gravel, about the size of peas or horse-beans, was laid on for a depth of six inches. On this was placed a layer of coarse sand for six inches, then one foot of fine sand, then one foot of finely-sifted cinders (not powdered), and on the top of all one foot of fine sand. The cinders in this case were taken from the heap outside the engine house, being riddled so as to remove all pieces above the size of a hazel nut.

The filter was started under a head of six inches, and the water percolated at the daily rate of 1,201 gallons per square yard. As this rate was greater than eesirable, the filter was stopped, and two additional effluent cocks were put in at a higher level. At the same time the top layers were altered to one foot three inches of fine sifted cinders, similar to the former ones, covered with nine inches of fine sand. The filter was started with three inches of head; the flow of water per square yard was as follows:

	Gallon.
1st day	.248
2nd "	.348
3rd "	.450
4th "	.433
5th "	.505
6th "	.467
7th "	.434
8th "	.434
9th "	.333

The quality of the water was good. It was almost clear and transparent, and had entirely lost its opalescent character.

The surface of the sand was now scraped, and as the rate was too small, the head was increased to five inches, with the following results;

	Gallons.
1st day	611
2d "	890
3d "	1,201
4th "	1,099
5th "	868
6th "	359
7th "	191

The water still remained slightly milky in appearance. In order to remove this the filtering materials were altered in the manner shown to be advisable by the house experiments. Instead of using the cinders and ashes just as they came from the heap, the heaps were riddled through a coarse sieve which retained only the cinders above the size of a walnut. These were washed, and afterwards well pounded into a fine black dust. The lower part of the filter remaining the same, the upper layer of three feet was then taken out, and replaced with fine sand, twelve inches; pounded cinders, six inches; fine sand on top, eighteen inches; total, thirty-six inches. The cinders were moistened before being put in, to prevent the dust blowing about, and were punned in rather tight. The filter was started with a head of one foot ten inches, when it yielded:

	Gallons.
1st day	240
2d "	168

The bottom valve was then opened, and the head made unlimited, when it supplied:

	Gallons.
1st day	352
2d "	354

The water on these four days was excellent. It was brilliantly clear and bright, all trace of milkiness having vanished, and analysis showed that its other qualities were equally improved. The speed, however, was too small, resulting from the too close punning of the cinders; the materials were therefore taken out, and replaced as follows: fine sand, eighteen inches; pounded cinders, six inches; fine sand (top), twelve inches: total, thirty-six inches. The materials were gently pounded in layers. The filter was started with a head of four inches of water, and yielded per square yard:

	Gallons.
1st day	231
2d "	175
3d "	200

On the head being altered to 10 inches, the rate of flow became:

	Gallons.
3rd day	636
4th "	601
5th "	768
6th "	997
7th "	991
8th "	1,100
9th "	1,141
10th "	1,137

The steady increase in the rate of speed with an unvarying head will be again noticed. The quality of the water, however, did not seem to be affected, but continued clear and transparent to the last.

On the following day the settling pools were drawn off for cleansing, and circumstances prevented the resumption of the experiments. This is much to be regretted, as the results now submitted can only be considered as fragmentary and incomplete.

It is evident that sand alone will not remove the turbid appearance from the water; but it would be desirable to continue an extensive series of experiments on the sand filter as first constructed, to procure precise data as to head of water requisite for different speeds of filtration, as well as to ascertain what results could be obtained in the way of purifying the water. Time did not permit of this then, as it was desired to ascertain, as soon as possible, what material would clear the water. It was intended afterwards to resume experiments on the sand filter; but this plan shared the fate of many other good intentions. Again, as regards the position of the cinder bed and the varying thicknesses of sand, no decided opinion can be given, inasmuch as the experiments never got beyond their first stage. Such as the experiments are, however, perhaps some general opinions may be deduced from them which it is probable further and more complete experiments would confirm.

It has been generally regarded as an axiom that, to procure efficient filtration, the speed at which the water passes the filter should not exceed 12 cubic feet per square foot of area of filter per twenty-four hours, or say 675 gallons per square yard per day. As regards this rate, if it can be preserved, the results obtained from these experiments justify the supposition that it is an effective one, and that it should not be much increased. The head necessary to produce this rate through an ordinary sand filter, such as is used in England, with a depth of material of from 4 to 5 feet, has been variously fixed by engineers at from 1 foot 6 inches to 2 feet. The maximum head allowed by Mr. Bateman is, the Author believes, 1 foot, the minimum being about 6 inches, the head varying in proportion as the sand becomes clogged and the porosity of the filter decreases. The experiments now recorded lead to the belief that even a head of 1 foot would be too great for such a filter, and that the proper head would vary between 4 inches and 6 inches. They also show that any calculations as to the average rate of filtration are fallacious. It appears almost impossible to preserve a uniform speed, which may vary with trivial and unavoidable circumstances to as much as double that wished for. The most trifling alteration of head seemed to alter the speed of filtration in a manner quite unexpected. Under an unvarying head constant variations would take place in the speed, while the well-marked tendency to a daily increase of discharge, when the conditions as to head and quality of the water are unaltered, is not the least curious part of the phenomena. Slight differences, also, in the mode of packing the materials have a marked effect on the discharge of the filter.

It would appear possible to effect some reduction in the thickness of materials composing the bottom of the filter. In the first construction, sand occupied the upper 2 feet of the filter, and beds of sand and gravel, gradually increasing in size downwards, the remaining or lower 2 feet. In the later construction of the filter these lower layers were replaced by two, each 6 inches in thickness, the lowest being of fine gravel, the upper of coarse sand. The results given by this latter construction as regards keeping up of the sand, were quite as satisfactory as those derived from the four layers, 2 feet in thickness, employed in the first instance, and it is believed that even the thickness of 1 foot might be further reduced.

In a sand filter, the sand being the real filtering material, it is desirable to have as great a depth of it as possible, not only to secure greater depth of sand and greater thickness to scrape from, but also to ensure a more uniform rate of filtration. The more homogeneous the materials of which a filter bed is composed, the greater chance will there be of maintaining a uniform rate of speed.

As regards the materials of which the filtering layers were composed, the variations introduced into these were suggested by the result of experiments carried on in the house. Numerous materials were experimented on, with unsatisfactory results in all cases except in the present one.

The Author was led finally to the use of cinders in the search after some material that should have extremely fine angles and points, and partly from his recollection of their usefulness in stopping leaks in canal banks. In the satisfactory results ultimately obtained, the ordinary cinders from the engine fires were riddled out from the dust and finer pieces; they were then well washed, and crushed to powder. At first the fine dust was separated either by winnowing it or by throwing the cinders into water and allowing the dust which rose to the top to flow away; but experience showed that the cinders so treated did not give a satisfactory result, the effluent water still remaining milky looking. To secure a perfectly brilliant pellucid water, it was necessary to pound the cinders very fine and not separate the dust.

It will be seen that in every case there was a marked increase in the hardness of the water after filtration. Looking at this, and knowing that certain salts had the power of precipitating the suspended matter, the idea naturally occurred that the clearness of the water was obtained from a chemical action set up by some element in the cinders, which would probably disappear in time. This does not, however, appear to be the case, inasmuch as no thickness of cinders cleared the water when they were not sufficiently fine or the dust had been removed, whilst a thickness of only 2 inches effectually did so when the cinders were finely pounded. Had the action been a chemical one the effect would, it was suggested, have been the same in both cases. It may be said that the pounding fine of the cinders allowed them a freer action on the water; but at one time a thickness of 1 foot 3 inches of fine cinders was used, and any extra fineness in the smaller 2-inch layer might be supposed to be more than compensated for by the great extra thickness of the coarser layers. The Author, therefore, was led to the conclusion that the action was purely mechanical, and that the clearing of the water was effected by the detention of the fine particles of mud by the needlelike filaments and points of the cinder powder through which they had to force their way. If this is so, it is natural to conclude that in course of time the filter would become clogged; but from the experiments in the house it seems as if this did not take place, at any rate for a long period of time, It would appear as if the amount of suspended matter escaping the sand, sufficient to give an opalescent or yellowish character to the water, is so excessively minute, that some time would elapse before any effect would be produced on the cinders. The principal part of the suspended matter is deposited on the top of the sand; when the surface is scraped the eye cannot detect any discoloration in the layer of sand below.

In the filter shown in Fig. 2, the thickness of the cinder bed is 6 inches, the thickness of sand above it being 1 foot, and below it one foot 6 inches. The lower layers are composed of 6 inches of coarse sand and 6 inches of fine gravel. This arrangement is not put forward as a sample of how the filter should be made, but simply as showing how it happened to be constructed at one particular stage of the experiments, when they were brought to a sudden conclusion. The construction of the filter rendered it necessary that the surface of the filter should be 4 feet above the bottom, and it was essential in any case to fill up the lower portion. No conclusions, therefore, should be drawn from this particular form. Experiments, continued for some time longer in the house, showed that excellent results could be obtained with a total depth of filtering matter of 1 foot, the cinder bed being 2 inches thick.

If it was desired to keep down the depth of the filters, an effective filter could probably be made with 6 inches of fine clean gravel, 2 inches of coarse sand, 6 inches of fine sand, 6 inches of cinders, and 6 inches of fine sand on the top. The thickness of sand on the top might be advantageously increased, so as to provide surface for scraping, without the necessity of disturbing the lower layers for some time. Experiments would be required to show how far such a construction as that recommended would be advisable. The filter shown in Fig. 2 was a success, and there can be little doubt that the whole effect of that filter was obtained in the upper 1 foot 6 inches, the remaining 2 feet 6 inches being useless as regarded filtration.

During the progress of the experiments frequent analyses were made of the water, both before it passed through the filter and afterwards, with the object of ascertaining the effect of the filter on the water. The system of analysis employed by the Author was that recommended by Professor Wanklyn, viz., the determination of the total solids in the usual manner; of the chlorine by means of a titrated solution of nitrate of silver. Free ammonia and of the albumenoid ammonia, produced by destructive distillation of the residue, were estimated by Nessler's process. Dr. Anderson has shown that this system cannot be depended on as a means of ascertaining the nitrogenous matter in water, for much of this matter has a greater tendency to combine with oxygen to form nitro-oxides than with hydrogen to form ammonia; consequently much of the nitrogenous matter frequently remains in the retort and is lost sight of, in the determination of albumenoid ammonia in the way proposed by Professor Wanklyn. In the present case, as only a comparative analysis was required, the system adopted may be considered sufficiently accurate.

The Author proposes to cite a few out of numerous analyses, as sufficient to prove the position he wishes to put forward. As regarded the sand filter, the water that passed through in the earlier experiments was little improved in quality, though slightly in appearance. Not until the head of water had been reduced to 1 foot, and a more regular rate of flow established, was any marked improvement effected.

On the 4th of August the analysis of a sample of water, taken from above the experimental filter, gave

	Parts per Million.
Total solid residue	342.00
Chlorine	42.00
Free ammonia	0.005
Albumenoid ammonia	0.24

Hardness 6°.

Water was then passing through the filter at the rate of 1,084 gallons per square yard of surface per day. A sample of water taken from beneath the filter on the same day gave

	Parts per Million.
Total solid residue	314.00
Chlorine	42.00
Free ammonia	0.008
Albumenoid	0.194

Hardness 6°.

This water was a good deal improved in outward appearance, but was still opalescent and yellowish. A slight improvement only had been effected in its character.

A sample of water from above the filter, on the 5th of September, gave on analysis:

	Parts per Million.
Total solid residue	357.00
Chlorine	39.00
Free ammonia	0.026
Albumenoid ammonia	0.23
Hardness 6°.4.	

A sample of water from below, on the same day, contained:

	Parts per Million.
Total solid residue	357.00
Chlorine	39.00
Free ammonia	0.013
Albumenoid ammonia	0.070

The state of the unfiltered water at this date was very good. It contained comparatively little sediment, but had the characteristic opalescent yellowish look peculiar to rivers of the class of the Plate. The filtered specimen was almost clear. It had entirely lost the characteristic yellow tinge, and merely retained a slight milky look. It was, as the analysis shows, considerably improved in quality.

The sample taken from below the filter on September 26th gave:

	Parts per Million.
Total solid residue	285.00
Chlorine	39.00
Free ammonia	0.018
Albumenoid ammonia	0.05
Hardness 7°.	

The rate of filtration when this sample was taken was 334 gallons per square yard per day. The water was crystalline, every trace of yellow having vanished.

The two following samples were filtered through a layer of six inches of cinders and of six inches of sand, a layer of about one inch of sand being spread over the cinders to keep them in their place. The specimens were filtered in the house through the small copper filter, the speed being at the rate of about 600 to 700 gallons per square yard per day.

	Aug. 10th. Parts per Million.	Sept. 12th. Parts per Million.
Total solid residue	214.00	242.00
Chlorine	42.00	39.00
Free ammonia	Trace	0.00
Albumenoid ammonia	0.03	0.01
	Hardness 10°.	Hardness 11°.

The water used for the purpose of obtaining these samples was in its usual condition. It may be taken as containing—

	Parts per Million.
Total solid residue	250.00
Chlorine	40.00
Free ammonia	0.05
Albumenoid ammonia	0.24
Hardness 6°. 5.	

Both filtered specimens were clear and crystalline.

Samples taken in October from beneath the experimental filter, when composed as shown in Fig. 2, gave equally favorable results.

Unless the water came away bright and clear the results, as regarded the albumenoid ammonia, were not satisfactory. In London the water companies, starting with a water containing 0.24 part per million of albumenoid ammonia are said to obtain a product containing only 0.07 part, more or less ; or in round numbers, they reduce the amount of albumenoid ammonia to one-third by the simple use of a sand filter. The Author never obtained such results. No filtration, however slowly or carefully performed, through sand alone, would remove more than one-half of the albumenoid ammonia. It was not until he succeeded in removing the color entirely from the water that he also freed it from the albumenoid ammonia. It would almost appear as though there were, in the case of the River Plate, some connection between the amount of albumenoid ammonia and the turbid yellowish appearance of the water. In almost every case where the desired result was obtained, there was a marked increase in the hardness of the water.

It is much to be regretted that these experiments were so fragmentary and incomplete. So far they indicate that the problem of purifying delta waters, such as those of the rivers Mississippi, Hooghly, and Plate, so as to render them clear and sparkling, is not difficult, and that it can be done a large scale without expense than that of ordinary filtration. Additional experiments would be desirable to determine the best position of the various layers composing the filter and their minimum thickness, when probably further interesting details might be obtained.

THE ICE-BOAT PROBLEM.

By Brvt. Maj.-Gen. Z. B. TOWER, Corps of Engineers, U. S. A.

In my paper on the Ice-Boat, published in the December number of this magazine, I assumed that the wind at right angles to the sail, giving the greatest propelling power, would also give the boat its maximum speed. This would be true if friction were the only resistance to motion. The air's resistance, however, complicates the conditions of the problem. General equations No. 5 in my last paper, introduced this element as a definite function of the variables and constants. These equations were wrought out at the moment of the magazine's going to press, and were not examined by me at the time.

They are as follows:

$$\left\{\begin{array}{l}\tan x=[(f+f'v^d)\sqrt{1+c^2} \\ \qquad +f''c(v+w\cos(u+x)^2] \\ \text{C.S.}(w\sin u-v\sin x)^2\sin x=\tan x\frac{\text{W}}{c}\end{array}\right.$$

$$(6)\quad \text{C.S. } w^2(\sin u-y\sin x)^2\sin x=\tan x\frac{\text{W}}{c}$$

When angle $(u+x)$ is greater than 90° its cosine becomes negative and is $=-\cos(u-x)$, the angle u being reckoned from the stern of the boat forward, instead of from the bow aft as in the original equations (5). As this angle u diminishes from 90°, the expression $-\cos(u-x)$ decreases more rapidly than $\sin u$ in the first member of the equation. Hence the resistance diminishing more rapidly up to a certain limit than the propelling power, the maximum speed will result from angle u less than 90°.

Equation (6) can be solved with reference to y and, by differentiation, an equation obtained showing the relations between angles u and x and factor c and the constants, when y is a maximum. But this resulting equation is too complicated for use.

The greatest value of y may be found, approximately, by the process of successive substitutions of different values for the three variables.

Equations (5) may be written thus, substituting $-\cos(u-x)$ for $+\cos(u+x)$.

$$(7)\quad y=\frac{1}{\sqrt{c}}\sqrt{\frac{\tan x-(f+f'v^d)\sqrt{1+c^2}}{f''w^2}+\cos(u-x)}$$

$$(8)\quad y=\frac{\sin u}{\sin x}-\frac{1}{\sqrt{c}}\times\frac{\sqrt{\frac{\text{W}}{\text{C.S.}w^2}}}{\sin x\cos x^{\frac{1}{2}}}$$

Let C be as before .008, S the sail's surface=400 square feet, W, weight of boat, 800 lbs.

f'' as found is equal to $\frac{\text{C}'\text{F}}{\text{W}}$, C′ being .005 lbs. the unit of pressure for small surfaces, and F number of square feet, which the boat exposes to the resistance of the air, including the helmsman.

Estimate of exposed surface is as follows:

Vertical section of mast (27 ft. by an average of 4 in)	=9	ft.
Being cylindrical its equivalent is $\frac{3}{4}$ 9 ft.	=6.75	"
Helmsman (side surface exposed to wind)	=5	"
Front or bow beveled 20′×$2\frac{1}{2}$″ =$4\frac{1}{6}$ ft.×.7	=2.92	"
Support of mast and iron rods, say	=1.33	"
Total	16.00	sq.ft

Substituting the above constants in eqs. (7) and (8) there results

$(f+f'v^d)$ being assumed$=\frac{1}{30}$

$$(7)\quad y=\frac{1}{\sqrt{c}}\sqrt{\frac{\tan x}{.09}-\frac{1}{2.7}\sqrt{1+c^2}+\cos(u-x)}$$

$$(8)\quad y=\frac{\sin u}{\sin x}-\frac{.52705}{\sin x\cos x^{\frac{1}{2}}}\times\frac{1}{\sqrt{c}}$$

From several successive substitutions of different values of the variables, I find the maximum of y to be, approximately, 1.84, corresponding to

angle $x=17°$

and angle $u=74°$, to 75°; or measured from the bow aft, with direction of boat, 124°, to 123° C being 1.6.

The friction on the ice is 31 lbs., and the air's resistance, 122 lbs.

Total resistance to boats motion 153 lbs.

These substitutions, however, have not been sufficiently extended to obtain the exact angles. In fact the variations, near the maximum of y, are so small, that a change of one or two degrees in u affects it but slightly. Each is probably within one degree of the true angle.

C′, the unit of pressure of the wind upon small surfaces, taken at .005 lbs., may be too large. It might be more correct to assume it .004, or even less, as the surfaces exposed to the air's resistance, making up the 16 square feet, are very narrow and do not hold wind.

With a sail that spreads 500 square feet, and C′ assumed =.004, y would doubtless exceed 2; that is, the boat would reach a maximum speed a little greater than twice that of the wind.

The value of the factor $c=1.6$ shows that the boat, sailing under the conditions assumed, has an excess of stability. For, if the height of the sail's center of figure is ten feet above the plane of the ice, and the boat twenty feet wide, the ratio of the moment of the boat's weight, to that of the pressure of the sail at right angles to the boat's direction, will be $\frac{16}{10}$.

It is an interesting problem to determine the values of angles u and x, and, incidentally, of the factor c, to enable the boat to work to the windward most rapidly.

That condition will be expressed by

$$\left.\begin{array}{r} v \cos(u+x) \\ \text{or,}\quad y\cos(u+x) \end{array}\right\} \text{a maximum.}$$

As the most recently constructed ice boats are made of one longitudinal and one cross plank, braced diagonally by iron rods, the canvas cover suggested in my last paper would evidently be inappropriate.

NOTE—On page 15, column 1, December number of *Magazine*, read, "The value of y in eq. C. S. w^2 (1-y sin $x)^2$ sin x=0, is

$$y=\frac{1}{\sin x}$$

instead of what is printed between the 17th and 24th lines.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—At the meeting of the Club held November 15th, 1879, nineteen members were present.

Mr. Percival Roberts, Jr., read "Notes Upon a Recent Decision of the U. S. Circuit Court, in the suit of Atkins Bros. *vs.* Edgemoor Iron Co., in this City."

The decision was in a suit brought to recover damages upon a lot of structural iron furnished by plaintiffs to defendant, who refused to settle the original account by an amount equal to expenses incurred in rendering said material suitable for intended use. Judge McKennan's charge to the jury cannot fail to be of great interest and importance, not only to engineers and manufacturers, but to all parties connected with transactions in constructive materials. It was the object of the paper not to criticise the rulings of the Court, but to make a few suggestions in regard to results arising from this decision, which will be cited in future, no doubt, as of much importance in legal disputes.

In this case there was no written contract; merely a verbal understanding and statement that the iron to be furnished was for special purposes.

The Judge, in his charge, said:

"That although there was no express agreement, still, under all the circumstances, there was an implied obligation on the part of the plaintiffs to furnish such iron as was suitable to be used in these structures * * * The law implies a warrant that the iron furnished under contract shall be adapted in quality and otherwise to intended use: and that if, at any time afterwards, it is ascertained and is satisfactorily shown that the iron was not of such quality as was fairly adaptable to the use for which it was intended, the warrant was broken, and defendants are entitled to damages."

The question naturally arises under such a ruling, when does a guarantee end?

Who shall be the judge of the fitness of material; what the criterion of its quality? It may be answered, the testimony of experts must be employed. But where are two experts who agree exactly as to the necessary qualifications for structural material?

Mr. Roberts further urged the importance of full and practical specifications being prepared for all work, and being transmitted not only to the builder, but also to the manufacturer. The questions brought out in this paper are also a strong proof of the urgent need, existing in this country, for thorough and systematic investigation of the strength of materials. This is work, the expense of which cannot be borne by individuals or corporations—the Government alone can bear so great a burden, but a burden made light by the vast importance of consequent results.

A Note upon "The Connecting Rod," by Prof. William D. Marks, was read by the secretary.

Mr. Billin read some notes upon the "Preservation of Timber." The opinions of many of our principal road-masters, in regard to the life of ties, seem to be very diverse. They, however, place the life of a white oak tie, cut when the sap is down, seasoned and laid in good gravel ballast, at between seven and ten years.

The majority of road-masters apparently live in blissful ignorance of the beneficial effects derived from the use of preservatives; and it is undoubtedly on account of such ignorance that more decided steps have not been taken in this country toward economizing our timber supply, and the cost of maintenance of way of our railroads, by increasing the life of timber used.

Some few experiments have been made within the last ten years toward strengthening the life of ties by Burnettizing, etc.; but the processes were applied in a very crude and imperfect way, and the partial failure of these experiments has done much toward preventing the introduction, now, of new and thorough processes.

It is estimated that seven million acres of timber are cut each year, in order to furnish ties for railroad use. These figures are not an exaggeration, and it is only astonishing that their magnitude has not, before the past year or two, attracted more attention to the subject and led to the adoption of some preservative process by our larger railroad companies.

Instances were cited of English creosoted ties which had been in use for twenty and twenty-two years, and were in as good state of preservation as when put in track. Creosoted piles driven at Portsmouth, England, forty-two years ago, were stated to have been found as good above water-line as below, and to have outlived sixteen and seventeen sets of piles cut from the same timber and driven in the same work, but which were not creosoted.

A further discussion of "Myers' Formula for Proportioning Culverts" was taken part in by Messrs. Herring, Darrach, and Cleemann. This subject has received much attention from several members of the Club; but an understanding of it cannot be had until the papers and various discussions relating to it are published in full in the proceedings of the Club.

Mr. J. E. Codman made some remarks upon the "Butler Mine Fire cut-off," and read a letter from Mr. C. J. Conrad in regard to it. The portion of this work where the danger lay was in the tunneled part, where it was feared that heating of the rock would carry destruction over the archway and communicate the fire to the seams in the workings of the Pennsylvania Coal Company; and, once there, no power on earth could have prevented it from working its way under the town of Pittston. All work at the fire was finished September 30th, and changes occurring since then have only served to confirm the announcement then made, that the Cut-off was a complete success. There was no question about the success of any portion of the work except the tunnel. The walls of this were built "dry," from eighteen to thirty-two feet thick, and eighteen feet high. The wall on the fire side was heated to a *white heat* through to the exposed face, but cooled-off in a few weeks. Finally, the great heat penetrated fifty feet of rock and earth, weakening, and disintegrating the mass, so that it crumbled and fell, filling the tunnel-space with broken rock; but this did not occur until the fire had spent itself and the walls were all cool.

American Society of Civil Engineers.—The last number of the Transactions contains an interesting paper on an important topic, viz.: Interoceanic Canal Projects, by A. G. Menocal.

After considering the various plans and routes, Mr. Menocal draws the following conclusions:

From the above statements and considerations it seems to follow:—

1st. That however desirable a canal at the level of the sea, partaking of the nature of a strait may be, to better satisfy the demands of trade, its execution, either with or without a tunnel, presents so many difficulties and doubtful elements as to place its probable cost out of the range of a successful commercial enterprise.

2d. That a canal with locks can be so constructed as to satisfy all the requirements of ocean navigation, at a cost within the possibility of a private undertaking, with reasonable expectations of liberal returns and without overtaxing the commerce of the world intended to be benefited thereby.

3d. That while a canal with locks seems to be practicable, *via* both Panama and Nicaragua, the latter route possesses greater facilities for the execution of the work at a reduced estimate of cost based on sufficient information to eliminate unknown elements, which might materially so alter the conditions of the project, as to cause painful disappointment to take the place of long-deferred hopes and cheering expectations.

And furthermore, that the geographical position of Nicaragua is more favorable to the United States, whose commerce will contribute more than that of any other nation to the business of the canal, while it will afford as great commercial advantages to foreign nations as other routes more to the south.

IRON AND STEEL NOTES.

Krupp's Homogeneous Iron.—After a long series of successful experiments Krupp has placed his "Fluss-Eisen" upon the market as a substitute for malleable iron. With a content of about one-tenth of one per cent. of carbon it resembles the best forged iron, but is superior to it. In large forged pieces it has a resistance of from 38 to 42 kilogrammes per square millimeter (54,046.7 to 59,735.8 lbs. per square inch). In sheet iron the tenacity is raised to between 40 and 48 kilogrammes (56,891.3 to 68,269.5 lbs. per square inch), with an elongation of about 25 per cent. and a diminution of 50 per cent. in the section of the experimental bar at the moment of rupture. The price is little higher than that of ordinary iron. The material is specially valuable for shafts, stern-posts, anchors, machinery, and all work which requires welding when it is made of common iron.—*Ann. du Génie Civil.*

A NEW industry for our iron mills, in which New England has succeeded tolerably well, but which has been made a specialty of in Eastern Pennsylvania, is the building of portable railroads for export to the West Indies. They greatly reduce the expenses of harvesting sugar cane, enabling the planters to transport heavy loads of cane quickly and cheaply from the distant fields to the sugar mills. The rolling stock used consists of light, four-wheeled platform cars, weighing less than a ton, which are capable of carrying over a ton of load. They are usually hauled by animals, but lately locomotives of very light pattern have been introduced. A portion of the plantation road often consists of a fixed track, from which branches of portable tracks are carried to the middle of the cane fields.—*Commercial Bulletin.*

RAILWAY NOTES.

AN improved system of tramways was described in a paper read before the members of the Manchester Scientific and Mechanical Society at their last meeting, by Mr. W. Telford Gunson, C.E. The new system consists in laying down a continuous length of stone sleepers similar to the kerbs now in use for footpaths. In these kerbs longitudinal grooves are cut 1⅞ inches deep, 3½ inches wide at the top, and 3⅜ inches wide at the bottom; the bottom of the groove is then covered with a ¼ inch layer of rock asphalte, and on this the rails are laid, the joints between the sides of the rail and the sides of the groove being filled in with a fusible mineral cement, thus firmly imbedding them in the sleeper, in addition to which they can, if desired, be further fastened down in the ordinary way. At the junction of the rails a quarter-inch iron plate, eight inches long, is inserted under the joint and lead run in, thus making the rails perfectly immovable. Mr. Gunson claimed for his system that it avoided all the well-known disadvantages of those at present in use, that vehicles of all descriptions could use it, and that whilst the cost of laying down was much the same, the cost of maintenance was considerably less than in other systems. The paper met with some criticism, and the discussion, in which it was urged that no tramway sytem would be perfect unless it was available for all classes of vehicles, was adjourned to the next meeting.

ENGINEERING STRUCTURES.

THE BRIDGE OF LESSART.—The Western Railway Company of France are at present engaged in constructing a branch line from Dol to Dinan; this has to cross the river Rance about two miles below the latter town by a single span at an elevation of about 100 feet. The method by which this has been accomplished is considered unique in this country, and deserves some notice. The iron portion of the bridge itself is of the usual diagonal construction; its length is 96.5 meters, or 314 feet, and its total weight 1,300,000 kilogrammes, equal to about 1,250 tons. It has been constructed by the Maison Jolly, of Argenteuil, a well-known firm, and has by them been put together on the line of railway immediately joining the intended span. Large wheels or rollers were placed beneath the bridge, and it was determined to push or propel the bridge across the stream by hydraulic power. In order, however, to regulate this operation, and to prevent its over-topping into the river below, a portion of a viaduct of a lighter construction, intended for another section of the line, has been temporarily attached or bolted to the fore end of the main span; this is about 150 feet in length, while another section is attached to the near end of the main iron bridge. It is evident that by adopting this method the fore end of the total iron construction will arrive at the supporting pier on the further side before the center of gravity of the main span will have passed that on the home side; it will then be supported at both ends until finally placed in position. As soon as this is accomplished, the two sections of the lighter viaduct will be removed. To M. Morse, engineer-in-chief to the railway company, is due the credit for this bold and original conception, and under his able direction and supervision this great undertaking has just been successfully accomplished.

IT has been reported from the spot that on the northern side of the Great St. Gothard, at Goeschenen, the works reached the exact middle of the tunnel at fifteen minutes before nine in the morning of October 31st. The distance was 7,460 meters, or four miles and two-thirds of a mile.

ORDNANCE AND NAVAL.

A FLOATING FIGHTING ISLAND.—Something more than rumor asserts that Messrs. John Elder & Co. have received an order from the Russian Government for the construction of an armor-plated war vessel, which is to be 500 feet long, to have a displacement of 17,000 tons, and to be propelled by engines indicating 10,000-horse power. With an average draught of say 22 feet, such a craft must have a beam of not much less than 75 feet to get the stated displacement. She will resemble an ordinary ship in very few respects. Presenting no side to the sea, her upper deck will be flatly curved, rising from the water's edge to the middle like the upper shell of a tortoise. She will, in a word, resemble a floating island upon whose sloping beach the waves will wash, rather than a ship. What her armament will be we cannot say, for, as may well be understood, the utmost reticence is for the present observed concerning this novel craft. She may no doubt mount six 100 ton guns, or perhaps eight, and may be fitted with a complete torpedo armament as well. Work is much wanted on the Clyde; and the construction of such a ship would afford employment for many months to come to hundreds of hands. It is but fit that the order should go to Messrs. J. Elder & Co., for it will be remembered that the late John Elder was one of the first, if not the first, to propose the construction of circular ironclads; and the ship concerning which we write will have much in common with his views. In May, 1868, he delivered a lecture to the United Service Institution, in which he proposed the construction of a ship of war, circular, propelled by a system of submerged propellers, and with a bottom of the form of a segment of a sphere. She was to be protected by a belt of armor and a deck of great strength, on which was to be mounted a turret suitably armed with guns. Whether a similar idea occurred to Admiral Popoff, independently of all knowledge of Mr. Elder's schemes or not, we shall not pretend to say. As is well known, the two circular ironclads which the Russians now possess are of little, if any, value for warlike purposes. The new ship is intended, no doubt, to act as a counterpoise in the balance of power to the great ironclads of Italy, and to our own Inflexible. For the moment, it would appear that the union of Germany and Austria leaves Russia isolated. The fact seems, however, likely to act rather as a stimulant to her warlike propensities than the reverse. It is well understood in certain circles that important fortifications, of which the world hears very little, are springing into existence on the shores of the Black Sea and elsewhere. Forts defended by Herr Gruson's chilled cast iron plates, some 2 feet thick, may play an important part in any future war.

BREECH-LOADING ORDNANCE.—A decisive step has just been taken by the War-office in reference to the breech-loading question. Orders have been given for the manufacture of two large breech-loading guns at the Royal Arsenal, one to weigh 25 tons and the other 40 tons. It is expected that these new and necessarily experimental guns will be completed by the middle of next year, though possibly a little latter. The precise method to be adopted as concerns the breech-closing arrangement is not yet disclosed; but it is certain that the guns themselves will be constructed on the Fraser system. Despite all attempts made to disparage that system, especially by the advocates of steel, it holds its own, and appears likely to do so. The forthcoming breech-loaders will have a thicker steel core than is customary with muzzle-loading guns of the same caliber, but that is simply due to the fact that greater thickness of steel is required in order to provide for the breech-closing arrangement. An important element in the new guns will consist in the unusual length of the bore, this elongation being designed to utilize the force of slow-burning powder. It is evident that breech-loading has recently risen in favor with the authorities, owing to the facilities which it affords for working guns of extra length. It is understood that the designs for these guns were prepared a year ago, and therefore long before the recent Krupp demonstration at Meppen. But the preparation of the designs was apparently subsequent to the experiments with Krupp guns at Bredelar and Meppen, in the months of June and July last year, at which trials General Younghusband, Superintendent of the Royal Gun Factories at Woolwich, was present, accompanied by Captain Morley, in accordance with instructions from General Campbell, the Director of Artillery.—*Engineer.*

BOOK NOTICES

MATHEMATICAL TABLES, CHIEFLY TO FOUR FIGURES. By PROF. JAMES MILLS PIERCE. Boston; Ginn & Heath.

The tables are—A table of Logarithms—A table of Logarithms of Sums and Differences—Logarithms of Circular Functions—Inverse Circular Functions—Logarithms of Hyperbolic Functions—Natural Sines and Cosines—Natural Tangents and Co-tangents—Natural Secants and Co-secants—Proportional Parts.

The explanations of the tables are fully given, but the entire book is only a thin octavo of less than fifty pages. The tables are clearly printed on heavy paper.

FUEL: ITS COMBUSTION AND ECONOMY. Consisting of Abridgments of "Treatise on the Combustion of Coal, and the Prevention of Smoke." By C. WYE WILLIAMS, A I.C.E., and "The Economy of Fuel," by T. SYMES PRIDEAUX. With Extensive Additions on Recent Practice in the Combustion and Economy of Fuel: Coal, Coke, Wood, Petroleum, Etc., by the Editor, DR. KINNEAR CLARK, C.E., Member of the Institution of Civil Engineers, Author of a "Manual of Rules, Tables and Data," "Tramways; their Construction and Working," Etc., Etc. London: Crosby, Lockwood & Co. New York: D. Van Nostrand, 23 Murray and 27 Warren Streets, 1879.

An important and timely book on a most important subject. The names of the authors whose treatises form the basis of the work are alone a sufficient guarantee of the value of the book. Most of those who think there is nothing left to learn in their practice of fuel consumption, will probably rise from a perusal of this work with surprise at their enlarged views of the real extent of the subject. The book should be in the hands of every owner of a steam-boiler, furnace, or other appliance for applying heat to industrial purposes. It is neatly bound in cloth, comprises 394 pages, with nemerous engravings and copious index, and its retail price is only $1.50.—*Scientific News.*

GIRDER MAKING AND THE PRACTICE OF BRIDGE BUILDING IN WROUGHT IRON. By EDWARD HUTCHINSON, M.I.M.E. London: E. & F. N. Spon. 1879.

In designing girders and bridges there are questions of an entirely practical character which it is necessary, with a view to economy, to take into consideration, as it is to apportion sectional areas to the calculated strains on different parts. It often happens that even first-class designs for girders are susceptible of modification when placed in the hands of the practical girder maker, not with a view to improvement from a theoretical point of view, but from that of practical expediency. When such works are in the hands of contractors resident in the same country as the engineer, these suggested modifications are easily explained and often accepted by the engineer. When, however, a set of girders is being made in England for an engineer, say, in India, it is often difficult to make any alteration in design or departure from the specification. Explanations take too long a time, and unless the modifications offer very great advantages they are not made. Books of the more theoretical character seldom contain much that will guide the designer from other than theoretical considerations. Mr. Hutchinson's book takes up the other phase of girder engineering. Girders or bridges of certain size, span, and number being required, and the design from a theoretical side being selected, the book before us steps in with the information necessary to enable the engineer to decide upon the best method of carrying it out. It gives hints on practical expediency which lead to the selection of forms and sections of iron which may be incorporated into the structure without any loss of efficiency, often with considerable gain in this respect, and with economy in cost. Part I. is upon materials, and after giving a brief account of the rolling mill methods of producing iron of different forms, which is of much assistance in guiding the writer of the specification, it instructs the engineer on the question of relative cost of different sections. These are points of much importance, as an engineer may often specify sections difficult and costly to make, not perhaps because there is any reason why such sections should be used, but because he is ignorant of the practical considerations which make some methods of producing billets or slabs, or rolling certain sections much more expensive, without being any more efficient than others which the ironmaker or girder constructor can suggest.

Some useful hints are given on making up girder flanges composed of bar iron of various sections. The second part of the work is descriptive of examples of girder and bridge work, chiefly as carried out by the Skerne Ironworks Company. The particulars of a large number of bridges erected in this country and abroad are given, illustrated by many well executed engravings. The method of erection of some of these bridges is described, and these descriptions are very useful and interesting.—*Engineer.*

Water Analysis. By J. Alfred Wanklyn. Fifth Edition. London: Trübner & Co.

The practical value of this work is sufficiently indicated by the fact that the present edition is the fifth.

The new matter is important, as it relates to the detection of the most important class of ingredients in impure water, a detailed account of the process of dealing with the organic matter being given for the first time in this edition.

A Treatise on Metalliferous Minerals and Mining. By D. C. Davies, F.G.S. London: Crosby Lockwood & Co.

This is of a popular rather than a scientific character, and describes, in a sufficiently concise manner, the condition in which most of the metallic ores are found. The metals to which the bulk of the space is given, are gold, silver, copper, tin, lead, zinc and iron. Bismuth, Mercury and Nickel receive a brief notice.

Considerable space is given to the mechanical part of Mining Engineering, and in this part particularly the illustrations are good.

The book would be more widely useful, and possess quite as much interest to the general reader, if, instead of the geographical and historical notes, there were inserted a brief guide to the determination of the principal ores.

Manuel De L'Ingenieur. Des Ponts et Chaussees. par A. Debouve. Paris: Dunod.

This ponderous work fills eighteen volumes of text and twelve atlases of plates.

The list of subjects embraces everything that is conventionally assigned to the department of engineering, so that quite a complete practical engineer's library is represented by theseries.

The details of the public works in and about the chief French cities, are given with elaborateness and finish that is quite rare except in the best French treatises.

In all that relates to works in masonry; to the management of rivers, to drainage or to construction of roads, no better models can probably be found than those afforded by modern French engineering, and which are fully described in this comprehensive work of Debouve.

The Art of Letter Painting Made Easy. By James Badenoch. London; Crosby, Lockwood & Co.

This very brief book instructs the beginner in drawing letters by geometrical rules. The models given are not of the best, but the instruction is carefully detailed.

MISCELLANEOUS.

Upon the question of the abolition of blasting in coal mines and in favor of wedging, the mining engineers of North Staffordshire are contending that if wedging should be insisted upon by the Legislature to the sacrifice of blasting, then that certain of the thick seams would have to be abandoned, since holding in such measures was next to impossible. The statistics, it is urged, show that the loss of life is much greater from the effects of wedging and falls of the roofs and sides, than from blasting; and the North Staffordshire engineers hold that if blasting should be prohibited there will be greater danger from falls of roof.

Tenders for the construction of the Adelaide sewers were sent in to the South Australian Government on June 16. The government intend using an area of 400 or 500 acres to utilize and pump the sewage, and this would be sufficient for effectually and efficiently disposing of the whole sewage of Adelaide and its suburbs.

The new arsenal and dockyard to be founded at Mihara for the Japenese navy will include dry and wet docks fit for the largest war-ships; iron sheds, in which iron and wood war-vessels may be built in any weather, as well as foundries, engine-shops, rolling mills, stores, &c. The expense of these works, it is expected, will be very great, especially as there are to be barracks and fortifications for their protection.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXIV.—FEBRUARY, 1880.—VOL. XXII.

A REVIEW OF THE THERMIC MOTORS EXHIBITED IN PARIS, IN 1878.

By V. DWELSHAUVERS-DERY.

Translated from "Revue Industrielle des Mines" for VAN NOSTRAND'S MAGAZINE.

The eminent physicist, M. Hirne, has discovered, experimentally demonstrated and measured, the thermic influence of the sides of the steam engine cylinder. Perhaps he suspected that it was caused by the condensation during expansion. But he proved that there was a continual exchange of calories between the sides of the cylinder and the steam, throughout the time of that mysterious transformation in which heat disappears in quantity proportional to the mechanical work performed.

In a review which professes a practical bearing only it seems inopportune to bring forward historical proofs of this fact; they will be reserved for another time and place.

The skillful and numerous experiments of M. Hirn and his disciples, have led to the determination in a rigorous manner of the economic results to be obtained from steam jackets, from superheating, from prolonged expansion etc., etc., and constructors have drawn valuable practical conclusions from these results.

But an economy which appears considerable when expenditure of steam is alone considered, diminishes singularly when we seek for a corresponding economy in the fuel. This indicates that the process employed in steam engines for conversion of heat into mechanical work is vicious in principle.

I hold to be able to prove this assertion, however discouraging it may seem, especially because I shall have before long to lavish praises upon those courageous constructors who have applied so much knowledge and sagacity to the improvement of this most powerful auxilliary of civilization, without however obtaining results worthy of their efforts.

So far only as the different elements act to exert an influence upon the consumption of steam, is it necessary to distinguish between the phenomena produced in the boiler, and those that take place in the cylinder. It is necessary to determine the weight and composition of the mixture of the water and steam which play so important a role, without occupying ourselves with the question of the origin of the steam. But to him who makes daily use of the complete machine, boiler and engine, the important question relates to the *consumption of fuel*, and it becomes important consequently to take it into serious consideration, as well as the mode of production and the mode of transmission of the heat to the intermediate body, the mixture of steam and water.

If we compare the economy that it is possible to realize in the *employment of* *heat in the engine*, with that which it is possible to attain in the *production of heat in the fire place*, we readily discover a marked advantage in favor of this latter part of the apparatus.

We proceed to demonstrate the above by calculation.

Suppose we burn under a boiler a coal of which analysis affords the following composition:

Carbon	$0^k.915$
Hydrogen	$0\ .035$
Oxygen	$0\ .026$
Ash	$0\ .024$
Total	$1^k.000$

We will take for the calorific powers of carbon and hydrogen 8,060 and 34,460 respectively. We will admit furthermore, in common with most authors, that an amount of hydrogen equal to an eighth part of the oxygen present ($=0^k.00325$) is already combined with the oxygen, and consequently can not aid in the production of heat by combustion. In other words the amount of hydrogen available for fuel is only $0^k.035 - 0^k.00325 = 0^k.03175$. The calorific power of the fuel is then:

For the hydrogen

$$0.01375 \times 34460 = 1094 \text{ cal.}$$

For the carbon

$$0.915 \quad \times 8060 = 7375 \text{ cal.}$$

Total calorific power 8469 cal.

We will next determine the amount of air required to complete the combustion.

Each kilo of carbon demands $\frac{8}{3}$ kilo of oxygen to burn it. Each kilo of hydrogen requires 8 kilos of oxygen.

We have then:

For the carbon

$$0.915 \quad \times \tfrac{8}{3} = 2^k.440$$

For the hydrogen

$$0.01375 \times 8 = 0.254$$

Total $2^k.694$ for oxygen.

In 9 kilograms of air there are two of oxygen; the weight of air necessary for the combustion of a kilogram of this fuel will be $\frac{9}{2} \times 2.694 = 12^k.123$.

The products of the above combustion will be:

Carbonic dioxide

$$0.915 \quad + 2.440 = 3^k.355$$

Vapor of water

$$0.03175 + 0.254 = 0.\ 28575$$

Moisture previously in the coal

$$0.00325 + 0.026 = 0.\ 02925$$

Nitrogen of the air $= 9.\ 429$

Ash $= 0.\ 024$

Total $= 13^k.123$

But if to burn solid fuel we admit only just sufficient air for perfect combustion, the burning is certainly incomplete, and a quantity of carbonic monoxide remains unconsumed.

In order to insure complete combustion of an average coal where a chimney is provided for draft, there is required an excess of air equal to about two-thirds of the amount which is chemically necessary. In the above example, therefore, about eight kilograms of air must be converted in with the products of the combustion, making a total of $13^k.123 + 8 = 21^k.123$.

The amount of heat necessary to raise the temperature of these products of the combustion of one kilogram of coal, through one degree, is determined by multiplying the weight of each of these substances by its specific heat, and taking the sum of the products.

For Carbonic Dioxide

$$3^k.355 \times 0.217 = 0.7280 \text{ cal.}$$

" Vapor of water

$$0.\ 315 \times 0.475 = 0.1496 \text{ "}$$

" Nitrogen $9.\ 429 \times 0.245 = 2.3101$ "

" Ash $0.\ 024 \times 0.200 = 0.0048$ "

" Air unburned

$$8.\ 000 \times 0.238 = 1.9040 \text{ "}$$

Total 5.0965 cal.

or a little more than five calories.

The above calculations relating to the fire assume an ideal condition which is unfortunately tacitly adopted, without closely defining it. This renders it necessary for us to explain what is involved in this ideal condition—this ideal *regimen* of the furnace.

The sides of the fire-place receive heat either by contact of the gaseous products of combustion or by radiation. But they emit heat also towards the interior of the fire-box and the flues. The heat penetrates to a certain depth in the sides of the furnace, but if these latter are made of properly refractory materials, the heat is not conducted to the exterior surface.

When the fire is first started these materials become heated to higher and higher temperatures, and to greater depths in their thickness. As the temperature rises, they radiate an increasing amount of heat, while the amount absorbed in a given time becomes less. It necessarily follows that the time soon arrives in which the quantity of heat received from the products of combustion by the sides of the furnace, is equal to that returned by the sides to the gases. Then the ideal regimen is established, and the heat developed by the combustion has no other effect than to raise the temperature of the products of the combustion.

Doubtless these gases are cooled by their contact with these surfaces, but at their origin in the fire there is a time when the heat of the combustion takes effect only in raising the temperature of these gaseous products.

When this *regimen* is once established, the 8469 calories developed by the combustion of a kilogram of the combustible will be employed only in augmenting the temperature of the twenty-one kilograms of products, and will effect a rise of one degree of temperature for an expenditure of each five calories. In other words, in the case we are considering, there will be a difference in the temperature of the materials put on the fire, before combustion and after it of

$$\frac{8469}{5.0965} = 1661 \text{ degrees.}$$

We have then, by burning a kilogram of coal, produced 8469 calories, and this heat applied entirely to the products of combustion has raised their temperature 1661 degrees.

Let us now assume, first, that the absolute zero of temperature is 273° below the zero of the centigrade scale; second, that the temperature of the materials, before burning is that of the outside air; say 15°. Then the *absolute* temperatures of the outside air and the combustion products are respectively:

$$273° + 15° = 288$$
$$273° + 1676° = 1949°.$$

The gases, therefore, in the fire-pits of our steam engines, may be considered as sources of heat, maintained, what ever the losses, at a constant absolute temperature of 1949°.

We will call bodies *cold* that are at the temperature of the surrounding air, whatever the source from which their heat (assumed at 288° of absolute temperature) is obtained.

If we transfer 8469 calories from a hot body to a cold one, employing the greatest possible amount in producing work, by aid of a perfect engine, we get by known laws of thermodynamics

$$8469 \times \frac{1949 - 288}{1949} = 8469 \times 0.852 = 7216 \text{ cal.}$$

which will each afford 425 k. m. of work, and also $8469 \times \frac{288}{1949} = 1253$ calories, which are not converted, but are expended on the cold body.

The 7216 calories utilized as work produce $7216 \times 425 = 3066800$ kilogrammeters.

This is the maximum of work that can be obtained from 8469 calories between the absolute temperatures of 1949° and 288°. In other words, by burning a kilogram of coal we have at our disposal 3066800 kilogrammeters of work, assuming that we employ our means to the utmost.

How do we employ this result?

A steam engine that affords a horse-power per hour for each kilogram of coal burned (that is, yielding 270 000 k. m.) may be classed among the most economical. (I know that results better than this are often claimed, and the claim seems to be justified by experiment, but I refer here to practical results obtained year by year and not to experiments limited to a few hours).

The efficiency of our best engines then is

$$\frac{270\ 000}{3{,}066{,}800} = 0.088; \text{ less than}$$

nine per cent.

What becomes of the other ninety-one per cent.?

Is not a process of utilization of heat which results in a loss of ninety-one per cent., vicious in principle? And if so, where is the fault? In the engine? or in the boiler? Where shall we apply the remedy for so great a failing?

We will proceed to reply to some extent to these questions.

In order to utilize the total fall of temperature, it becomes necessary to reduce the temperature of the gases in absorbing their work, till their temperature falls from 1676° to 15°. Or if by means of this heat we raise the temperature of another body, it becomes necessary that these products of combustion be cooled with useful effect to the temperature from from whence they started, or 15°.

Now this is impossible with our steam boilers. The products of combustion leave the heated surfaces with a necessary excess of temperature; this excess constitutes the first considerable loss, and is inherent in our methods of employing heat.

In order to fix our attention to a particular case, suppose that a boiler is furnishing steam at six atmospheres pressure, or a temperature of 159°.22 in a continuous manner. Throughout the inside of the boiler then, the surface of the iron is in contact with a fluid at a temperature of 159°. In order that there should be a transfer of heat from outside to inside of the boiler, it is necessary that the external surface be in contact with a fluid whose temperature is above 159°. I believe it is no exaggeration to say that there would be no real transfer of heat if the products of combustion exterior to the boiler were not raised above a temperature of 250°. According to this, the heat of the gaseous products ceases to be useful at 250°.

Then the loss from this source is the heat necessary to raise these gaseous products from 15° to 250°. For each kilogram of fuel this is

$$5.0965(250-15)=1198 \text{ calories.}$$

From the employment, therefore, of gaseous products of a combustion as an intermediate body to furnish heat to the water of a boiler through the metal sides, there results a loss of

$$\frac{1198}{8469}=0.141$$

or fourteen per cent.

Some authors have attributed this loss to the draft of the chimney, and have proposed to replace the chimney by a forced ventilation. They call this fourteen per cent., the "cost of the draft." Aside from the expense of building the chimney (the real cost of the draft), the actual expenditure of heat necessary to accomplish the work of the draft may be neglected.

Of the 8469 calories produced, there is afforded to the water in the boiler, no more than 8469—1198 or 7271 calories; a little less than eighty-six per cent. of the original amount, (0.859).

These 7271 calories are converted into useful mechanical work only through the act of vaporization, and which is brought about at the constant temperature of 159°. The water has then to be introduced against a pressure of six atmospheres, and heated to 159° before any useful effect is obtained from it.

The number of calories expended in introducing the water and raising it to the required temperature, we will call the "expense of feeding the boiler."

As the heat which corresponds to the expense of feeding the boiler, does not contribute directly to the production of useful work, it becomes a second cause of loss, and is to be added to the preceding. We will proceed to estimate it.

In order to raise a kilogram of water to a height of ten meters, and to feed it to a boiler against a pressure of six atmospheres, it is necessary to expend about 62 kilogram meters of work, or about 0.146 calories.

Suppose the temperature of the feed water to be 35°, a fair means for condensing engines. The heat contained at this temperature=35.037 cal., at 159° the heat is 160.835 calories; the difference, 125.8 calories added to 0.146, as above gives 125.944 calories as the expense of feeding the boiler.

Aside from the loss by radiation, there is taken from the heat that is afforded to the water 125.944 cal., as the expense of feeding. From this there is a further amount expended to vaporise the water at the temperature of 159°.22.

This amounts in all per kilogram of water to;

$$606.5+0.305\times159.22-35.37=620.625 \text{ cal.}$$

Therefore of the 620 calories supplied, as the cost of feeding is 126, the percentage is

$$\frac{125.944}{620.025}=0.203$$

or a little more than twenty per cent.

Of the 7271 calories introduced into the boiler, there are 7271+.203=1477 which are also lost so far as mechanical effect is concerned. Only 5794 of the original 8469 remain, equal to 0.684, or about 68 per cent.

We are yet far from having taken all the losses into account. We now call attention to a third cause of loss.

We have seen above, that if there was a fall of temperature from 1676° to 15°, that 1253 calories passed to the cold body without producing useful effect, and that this was a minimum loss, and based upon the hypothesis of a perfect engine. But the employment of steam as an intermediate agent for the proproduction of work, by expenditure of heat, changes the conditions. The highest temperature is now 159° and the lowest 15°, that of the water in the condenser. Under these conditions, the minimum of heat that should pass to the cold body without producing work, is

$$\frac{273+15}{273+159}=0.667:$$

this is to be taken in place of 0.148 which we found before for the temperatures of 1676° and 15°.

The reduction of temperature caused by employing vapor as a second intermediate agent, gives rise to a loss of

$$0.667-0.148=0.519$$

or about fifty-two per cent.

We will estimate this in calories. Of the 5794 calories expended in a perfect engine, between the temperatures of 159° and 15° there are two-thirds or 3863 which pass to the cold body without work. Between the temperatures of 1676° and 15° the loss would be only 1253, a difference of 2610 calories in 8469 or thirty-one per cent.

A recapitulation of the foregoing is herewith presented: An ideal perfect steam engine with a suitable boiler, working under conditions as cited above, and which are practically medium ones; out of an expenditure of 8469 calories can only utilize as mechanical work,

$$5794-3863=1931$$

which is $\frac{1931}{8469}=0.228$: less than twenty-three per cent.

The defective mode of utilizing the heat in steam engines results then in a loss of

$$0.852-0.228=0.624$$

or sixty-two per cent. This is the estimated minimum loss of a perfect engine.

Our best steam engines render 0.088 as we have seen. The total loss then, is 0.852−0.088=0.764, or more than seventy-six per cent.

Between 0.228 and 0.088 there is a difference of fourteen per cent. This is all that is to be gained by improvements of the steam engine that leave untouched the prime defect. With this defect the consumption of coal will never be less than

$$\frac{0.088}{0.228} \text{ or } 0^k.386 \text{ per horse-}$$

power per hour. It is evident that the field for improvement is much vaster for him who seeks to perfect the mode of utilizing heat from its origin, than for him who considers only the mechanism of the steam engine. This we believe is the end to be sought by those who seek to improve gas engines or gas furnaces.

As we are to present calculations upon gas engines, we will first seek to determine the least expense that we can hope for in these motors. Then we can judge more easily of the extent of the possible improvements.

It is not easy to get exact statements in regard to the composition of illuminating gas. Its density also depends upon conditions that we do not pretend to consider here. We will take such figures as seem to represent a medium composition and weight.

Carbon	$0^k.605$
Hydrogen	0 .212
Oxygen	0 .077
Nitrogen	0 .106
	$1^k.000$

The weight of a cubic meter at a mean temperature and pressure is $0^k.585$, the same volume of air weighing $1^k.3$.

To determine the calorific power, we deduct from the amount of hydrogen $0^k.0096$, one eighth of the weight of oxygen, as being already combined with oxygen. We have then for the hydrogen available for fuel, $0^k.2024$. Multiplying the carbon and hydrogen by their respective calorific powers, we get

$0^k.2024 \times 34460 = 6975$ calories.
$0^k.605 \times 8060 = 4876$ "

Total $= 11851$ "

To determine the quantity of air required, we proceed as in the case of coal.

For Carbon $\frac{8}{3} \times 0.605 = 1^k.613$ oxygen
For Hydrogen $8 \times 0.2024 = 1.619$ "

Total $= 3.232$

The air required being $4\frac{1}{2}$ times this, we have; $14^k.546$ of air for each kilogram of gas.

The products of combustion are;

Carbonic dioxide	$0.605 + 1.613 =$	$2^k.218$
Vapor of water	$0.202 + 1.619 =$	1.822
Nitrogen originally 0.106 } " with the air 11.314 }		11.420

If the heat of the combustion were entirely employed in augmenting the temperature of the products, this rise of temperature could be deduced by employing the specific heats of the substances as follows:

Car. dioxide	$2^k.218 \times 0.217 = 0.4813$	cal.
Steam	$1.822 \times 0.475 = 0.8655$	"
Nitrogen	$11.420 \times 0.245 = 2.7979$	"
Total	4.1447	"

The augmentation of the temperature is therefore

$$\frac{11851}{4.1447} = 2859°.$$

Such a temperature being too intense, it is necessary to diminish it. The reduction in the Otto-Gas-Engine is brought about by the admission of a liberal supply of inert gas to mix with the combustible. In this engine, which renders good practical results, there are added to $15^k.546$ of the products of combustion, $10^k.793$ of the same composition. Consequently there is a total of $26^k.339$ of gaseous products, which require

$$4.1447 \times \frac{26.339}{15.546} = 7.0222 \text{ calories}$$

to raise the temperature one degree.

Then the rise of temperature in the Otto engine with constant pressure would be

$$\frac{11851}{7.0222} = 1688°$$

In this engine it is not probable that this temperature is attained, because a part of the heat is absorbed by the work during the combustion. Another portion is absorbed without useful effect by the cold water employed about the moving parts to prevent overheating.

But to determine the efficiency of this motor, we must compare it with an ideal engine, which, expending 11851 calories, experiences a fall of temperature of 1688°.

For this purpose we will suppose that the temperature of the cold body, the outside air is at 0°, or 273° above the absolute zero.

A perfect thermic motor would afford in work

$$425 \text{ k m} \times 11851 \times \frac{1688}{1688 + 273} =$$
4,335,570 kilogrammeters

for each kilogram of gas burned.

It follows that a cubic meter of gas would afford

$$4335570 \times 0^k.585 = 2{,}536{,}308 \text{ k.m.}$$

The Otto engine consumes about a cubic meter of gas for a performance of one horse power per hour; that is, it yields 270 000 kilogrammeters of work for a cubic meter of gas.

Its efficiency then is

$$\frac{270000}{2536308} = 10.64 \text{ per cent.}$$

This is the result as measured by the friction brake; but if we measure by the indicator, as is done in steam engines, the result is considerably modified.

The consumption for each indicated horse-power per hour is only two-thirds of a cubic meter of gas. That is to say, the Otto engine measured by the indicator exhibits a performance of

$$\tfrac{3}{2} \times 10.64 = 15.96;$$

nearly sixteen per cent., which is about double the efficiency of the steam engine.

If we do not regard the price of the fuel, the gas engine is superior, in point of efficiency, to the steam engine.

Much remains to be done in improving the gas engine. But the margin for improvement is less than in the steam engine, or than in any motor employing a fluid heated through an envelope, by gaseous products of combustion.

The principal cause of loss in the Otto engine, exists in the high temperature at which the gas is released after its expansion in the cylinder. We have been able to verify the statement that the gases at their exit have nearly 900° of heat. Now if we could expand them to zero, utilizing the heat in external work, we should regain forty-five per cent. Evidently this is practically impossible. But in the steam engine, besides the *practical* impossibility of realizing twenty three per cent., there is the *theoretical* impossibility of ever passing this limit by reason of the mode of employing the heat.

The gas engine in the most perfect form known to-day, is susceptible of great improvement, incomparably greater than can possibly be made upon the steam engine.

COMMON SENSE IN ARCHITECTURE.

From "The Builder."

Paper read at the meeting of the Architectural Association by Mr. COLE A. ADAMS.

Mr. Fergusson, in the admirable introduction to his "History of Architecture," says; "Convenience is the first thing which the practical common-sense of the Aryan seeks, and then to gain what he desires by the readiest and the easiest means." From this ancient Aryan stock John Bull claims descent, and common sense is a very strong article of his creed.

When and wherever architecture has been practiced as a living art, as the outcome of the wants of the people who practice it, especially in those styles and ages which are generally reckoned by the educated as the purest, this quality of common sense is everywhere recognized, as their works are eminently practical and logical. From the rock-hewn cave and rude hut to the stateliest edifice this principle will be found to exist, and though a common-sense building may have no artistic beauty, a building which sets common sense at nought will fail to please the intelligent observer.

Of the æsthetics of architecture I do not propose to treat this evening (except so far as may be necessary to illustrate my meaning), but rather of the practical side and of modern times, as it is difficult in the short time at our disposal to take a very wide range of the subject; but I shall endeavor by illustration and example to point out the necessity of common sense in architecture, and to show that where it is ignored or wilfully omitted that building cannot fulfil the conditions of art.

Common sense is a gift which is not implanted in the breast of every man, and where it is, it must, like every other talent, be cultivated so that it may gain strength by experience. But the man who adopts any profession or trade is expected by those who employ him to exercise this quality, to cultivate it, and bring it to bear upon the work he supplies; and this, more especially, in a profession where those habits known as business ones form a large part. In our calling it is essential, in the interest of our clients and the nature of our business, that we should strive to conduct it on common-sense principles, for any departure from this will lose us respect and influence in the minds of our employers, the mischief arising from which will extend beyond ourselves, and weaken that respect which we should strive to hold in the eyes of the public.

The charge often brought against us as a body is this want of common sense, that we are not practical, and many find a peculiar pleasure in pressing this accusation. Every blunder committed and brought to light in building must be laid at some door, and our accusers are happy if that door has the name of an architect upon it. Charges of ignorance in sanitation, which, at the present time, is exciting, as a science, so much attention, are hurled at us broadcast, and this is done by people who, if they exercised the common-sense maxim of looking before they leaped, would hesitate, and first ascertain whether an architect had been employed at all on the work which they condemn, and bear in mind that a very large amount of building is carried out quite independently of our services—that by far the larger number of us are lodged in houses provided by the speculative builder, whom it is not incumbent upon me to defend. He is a most useful man to the public, is created and supported by them, provides wares to suit all pockets, and it is, at least, a little unfair to charge him with the faults inherent in the article which he somehow contrives to sell the public for a sum absurdly below what such an article would cost were it made of true metal.

Further, where this charge of want of common sense is brought against us, the question will arise, What is common sense? You think so and so, and I differ from you. On the whole, considering that I make a study of my work, I ought to know best. Such questions as this must and do arise, and it would be impossible to lay down definite rules, and say this work possesses, and this other does not possess, common sense.

It is easy, of course, to quote gross cases in which this quality under discussion does not exist. For instance, a house without a staircase, a living room without a window, a house built without proper foundations, or in the midst of a swamp, and expected to be dry, when no provision has been made to guard against the situation, and so on. Here, perhaps, we should all agree that no defense could be made, and we have no hesitation in saying that the persons responsible for such doings lack common sense.

Let us also take other examples which require a higher perception of this faculty than those just quoted. We have in the present day a rich store of illustrations of the architecture of the past ages, and I think you will take it for granted that the building generally tells you the purpose for which it was erected, if you are familiar with its style, and we all agree that a work should express this common-sense requirement. But often in modern times we find that this is ignored. In the Gothic revival, a movement which has been so beneficial to us as a nation, it is not to be wondered at that enthusiasm carried many of its disciples beyond the region of common sense, and that blunders were made which we must deplore. In the rage to build everything Gothic, the world containing the relics of the past has been ransacked, and the treasures gleaned have often been misapplied. Let us take an ordinary dwelling house, for instance. It is not unusual to find the porch looking as if it had been brought from some village church, and though it fulfils its practical common sense purpose, it does not commend itself to common sense intelligence, which demands fitness and expression of the use for which the work is intended. Neither are we impressed, on entering a small hall or dining-room, to find a chimney corner recess large enough for a spacious apartment, and there appropriate enough, but out of scale altogether where spaciousness could not be obtained. Common sense seems to demand that the fireplace should be proportioned to the scale of the room. Attempts, too, have often been made to plan houses on mediæval lines, ignoring the fact that the world has grown older and more civilized, demands refinement of plan and has introduced requirements which can only be met as they arise. Instances might be found where the dining room has been so placed that it had to be traversed by any person requiring access to the stairs or kitchen, and this not from want of skill, but from a desire on the part of the architect to reproduce the simplicity of living as it existed in the past. As well may we try to persuade people to go back to the inconvenience of the old stage coach and the slow delivery of letters. Yet many of you must know that attempts almost as unreasonable and deficient in common sense have been made by many men who, instead of seizing the spirit of the past, and designing in it, seek to reproduce the letter, and are imitators only. Again, we sometimes see a church-like gable and traceried window engrafted upon a house in the part occupied by the staircase, and looking more like a private chapel. The whole does not express its purpose. Both gable and window were right where they originally came from, but, transplanted, the incongruity is apparent to intelligent criticism. The butler carrying the dinner up this staircase in monk's garb would be thought quite out of place, and yet, would it be much more incongruous?

Church restoration and building both offer much food for reflection, as the most prominent result of the revival. The difficulty of building houses successfully in the Gothic style has always forced itself upon the attention of the designer. Our mode of living is so out of joint with it that it promises soon to go out of fashion for domestic purposes; but for ecclesiastical buildings it will probably survive, though even here there are signs of reaction. Now, as to restoration. The use to which our churches are put will vary according to the requirements of those who use them. Our days witness a return, in a large party of the Church, to more ceremonial observance. Previous generations had in their day ignored ceremonial, and at the Reformation had cleared the churches of all that, to their minds and teaching, symbolized the faith of their fathers. With the enthusiasm of the time a clean sweep was made of everything that served to recall the hated doctrines, and, from their point of view, it was a common-sense proceeding. These things represented, to their eyes, error and false teaching. Away with them. We know what followed. Whitewash, ceilings plastered up, churchwarden additions, pews, galleries, three-deckers. Then came the revival in church principles, and the demand for buildings which should act their part in teaching these, and men set themselves busily to work to restore and build churches to this end, and the example has been followed even by those who still adhered more strictly to the spirit of the Reformation. The religious aspect of this question is obviously only touched upon here to illustrate the reason for this change. If, as we have seen, the Reformers looked upon the building and its furniture as of no importance in teaching doctrines, the revivers of ceremonial in our day insist upon the building and furniture fulfilling this purpose, and so making use of the senses by external teaching. This being so, it is obvious that our churches, as they were some half century ago, were a standing protest to the new school of divines. They demanded that, for the proper and reverent conducting of the services, all those fittings and additions which we know as "church warden" should in their turn be swept away. As men's attention was called to our churches, the beauty of them became a popular study, and we all know how the enthusiasm spread, and what it has produced. This revival in the Church demanded, as we see, a return to the teaching of art as part of its system, and though its advocates do not insist upon it as a necessity of their creed, they welcome its use, as soldiers do the colors under which they serve. From this point of view, I think it may be granted as a perfectly common-sense way of effecting their end.

From the zeal with which the restoration of our old buildings has been carried on, much irreparable mischief has resulted. It is a natural consequence that it was so; for experience must be bought. What we have to look to is to buy it at the lowest rate possible. Seized with alarm at the blunders that have been made, many have rushed to the opposite extreme, and would stay the hand of the restorer altogether. These worthy people, actuated by honest motives, would leave the buildings as they are, or only do what was absolutely necessary to prevent their decay, by keeping out wind and weather. As archæologists and students, it is impossible to withhold sympathy from such intentions. With what delight do we enter a church where we find the whitewash and grey hairs of age! Here there is no mistake likely to arise as to what was part of the original building and what is churchwarden. You would probably after a little study of it be prepared with a scheme for restoring the fabric; but you doubtless will miss a great deal of pleasure if, on paying a visit to it at another time, you find your old friend with its hair dyed, and made young again, by some other restorer. But suppose the anti-restoration men had their own way. Decay we know is the mortal inheritance of all earthly things, and does not common-sense experience teach us that there is a limit to patching and propping; that circumstances often arise, over which we have no control, which necessitates radical alterations; that our buildings are from time to time put to new uses to which we must bend them or else leave them to decay? Leave them, say some; build others for what you need, but touch not with altering hand these stone books of the past. But, says common sense, these buildings were erected for the purposes of worship, and men in previous years adapted them to their needs. This dedication to their high purpose is the most important, and therefore, as long as they afford shelter and can be made use of, men will avail themselves of them. Your interest in them is altogether secondary to this. Is it not impossible to lay down definite rules of what shall and shall not be done? Common sense must be used, and, further, we may say that, in dealing with such treasures as are bequeathed to us, only those well skilled in the work to be restored should be employed; and it is a pity that we have not some central authority to restrain such work from falling into the hands of men who, from want of sympathy with and ignorance of what they undertake, do an amount of mischief which is beyond recall.

In the building of new churches, common-sense requirements are too frequently overlooked. Here, as in other things, men forget that the world has moved on since the time that it produced the works that we admire, and that the more artificial life we lead now requires that more attention should be paid to the comfort of the people who are compelled to worship in cold and draughty churches. Because great simplicity in all such matters is found in the old churches, that, surely, is no sound argument for not seeking improvement in new ones. Now it is only common sense to know that, if you have a door opening direct into a building, and the weather is cold, the chilled air will enter by it, and make those people miserable who are in contact with the draught occasioned. Architects seldom dream of doing this in any other building where people assemble. We all know that in a house, where the money to be spent will allow, screen-doors are put to a hall, and in most cases some sort of a passage cuts off access from an external door and a room door. Why, then, should a congregation be exposed to danger,—for real danger it often proves to be,—by omitting so simple an expedient as a lobby of some kind? Contrast the comfort of a church or chapel where this is done with one unprotected from the blast.

Another serious omission is the absense of any mechanical and simple contrivance for admitting fresh air from outside, and warming it before it enters the building; for in winter, and the one we are having now calls our attention to the fact, it is misery to sit in a building with the windows open; so a close and stuffy atmosphere has to be breathed, no means existing to get rid of it and to supply fresh air in its place.

Other great causes there are which militate against warming our churches, —the large amount of glass, and the open roofs, both great chilling surfaces. Moreover, sometimes the boarding to the roof is not tongued, so that the hot air finds a ready escape, and so the heating apparatus is comparatively useless.

Common sense in planning is often sacrificed to supposed architectural effect, and as seeing and hearing are the most important points to be met for the comfort of a congregation, although where the means at disposal are limited, some sacrifices to effect may readily be granted; yet where this is not the case it is assuredly foolish to so seat the congregation that their view and light are interfered with by facing walls and other obstructions. These are difficulties that arise, and to ignore them for the sake of carrying out some likeness to what we have seen elsewhere, and for which, probably, sound reasons might be advanced, is a confession of weakness, and to this error may be attributed much of the lifeless work we have in our midst.

What a perfect medley do some designs present: here part of a monastery, there of a church; details reduced so in size from the originals from which they were taken as to look starved and wretched; chimneys overtopped by high roofs that will be sure to make them smoke; buttresses to resist no thrust; windows stuck in for appearance, coming anyhow to the rooms, now close to the floor, now above looking-out level; roofs that must from their construction thrust out the walls; passages ill-lighted, and tortuous in their windings,—these and other mistakes arise from ignoring the common-sense requirements of the purposes for which the building is intended, and with the mistaken idea of producing architectural effects by trusting to appearances only. Careful consideration of the plan, and working out of heights and sections of the construction, would have shown the designer his mistakes; and a more intelligent studying of the works which fill his sketch book, that what looks well and suitable in a position for which skill has designed it, may become ludicrous if placed in a position which is foreign to its original purpose.

I cannot leave this part of my subject without a brief allusion to the style which has somewhat quenched our Gothic ardor, and which, for want of a better name, is called "Queen Anne." I believe I am right in saying that its sponsors promised in its name essenti ally common-sense qualities, and that it would more readily adapt itself for house architecture and modern wants. In my own opinion, I think there is much in it to commend itself as a style, but it is possibly only the prelude to a revival of Classic architecture. Here, as in the Gothic revival, men are and will be found hunting up old examples, and trying to make new houses look as much like old ones as possible; and as long as imitations are the fashion no real progress can be made. Touching Queen Anne, common sense may ask, why is it necessary to return to small panes of glass, and thick bars which obstruct the view, when you can get larger? Would the old builders have put them if they had not been obliged? Why is it that porches are built, and cut off short of the cornice, looking as if you had not bricks to finish with? To get light into the hall? But surely you can do this without resorting to so foolish an expedient. And why, in this dirty London climate of ours, do you paint your outside doors white or pale dull greens? After the first week's use they are dirty and disagreeable to look at. And while on the subject of painting, a great deal has been said against graining and varnishing; it is decried as a sham. But if you will soothe your conscience by calling it a conventional mode of decorating doors, &c., you will have a most useful agent. Beyond all question, for ordinary purposes, there is nothing that on the whole wears better, looks better, and goes better with the ordinary furniture and belongings of a house—a thoroughly common-sense method. But, to resume, why is it necessary to stick up tablets on blank walls, in all manner of positions, looking as if they had been bought up from a church under restoration, and set up here as a protest against the vandalism that removed such precious works of art? Why, too, we may ask, is it necessary to be putting balconies, balusters, and railings where they are not wanted at all? And other questions of this kind will be forced upon you, if you will take a walk in the neighborhood of the Thames Embankment or Pont-street, and study the designs which are weekly supplied to us.

Much of the charm of the red brick style consists in its color, and there is no doubt that it has great capabilities when used with skill and sobriety. Too much of what we see is rendered feeble by the fussiness displayed and the ignorance shown in the mouldings, which are too often of a nondescript form.

I will, in conclusion, make a few remarks upon some of the causes which conduce to failure and violations of common sense, hoping to fulfill the object of this paper by exciting discussion upon it. I believe that the main cause lies at the root of professional training. Lads are articled to an architect, and left in the office, too often, to shift for themselves. You all know the usual course, so I need not stop to describe that; but I would urge the importance of reform,—that it should be an understood thing in the articles of agreement that a pupil should spend a large part of his time upon works in progress, that he might see for himself what drawings mean when carried out, learn the different modes of construction,—from foundations to painting,—be compelled to make measured drawings from the work, accurately showing how the parts are put together, and to make himself familiar with the terms and methods used in building. Better still, that after his pupilage was up he should, if it can be managed, be sent for a couple of years or so to a large builder, and there taught the practical side entirely of the question, even to manual labor, and that perplexing study, a builder's account. Engineers do this, and their works are pre-eminent for common-sense. Why should not architects make themselves also familiar with the capabilities of the materials in which they will have to work? The knowledge thus gained, combined with the experience of the office, and careful and systematic studies from old examples, would produce men skilled, theoretically and practically, in their profession; and to those within reach, the Architectural Association offers immense advantages.

That we, as a profession, should hit upon some feasible plan by which competitions might be conducted on a fair footing, is much to be desired, and I trust that when the subject comes up here for discussion, some remedy will be found. If the Institute and yourselves were to combine to resist the injustices of the system, much might be done to discredit it. One thing we may assume as certain. The competition system exists, and is more or less popular. What is asked for is fairness from projectors and among competitors themselves. The appointment of a skilled professional man as referee seems a necessity, for this very commonsense reason,—no layman is competent to decide upon designs, and discriminate between rival merits. If competitors knew that designs must undergo the scrutiny of plan, sections, and details, those crucial tests of a man's practical knowledge, better designs would be sent in, and the simply draughtsmen-architects would be nowhere. Too much stress has, I believe, of late years been laid upon this quality of draughtsmanship and sketching. Excellent as accomplishments, they are not the be-all and end-all here.

USELESS BOILER SURFACE.

From "The Engineer."

More or less intimately connected with every apparatus intended for the generation of steam will be found a certain protion of surface which is of no direct use. This surface costs money in the form of capital to begin with, and may require for its maintenance in good order a further expenditure from time to time. A further objection to it is that it always represents weight, and it is consequently under certain circumstances very desirable that it should not exist. The difference between a good and a bad boiler not unfrequently lies wholly in the amount of useless surface possessed by the latter. Not quite so much importance has been attached to the subject as it deserves. If it were more considered, fresh departures in boiler engineering would probably be made with advantage.

Useless surface may be defined as that which adds nothing to the steam generating power of a boiler, and answers no other purpose in the best possible way. For example, the sides of the brick flue in which stationary boilers are set are useless for the generation of steam. The whole of the lower portion of the cylindrical flues of Cornish and Lancashire boilers, and the bottoms of the furnaces of marine boilers contribute nothing to the production of steam. It may of course be said that by using cylindrical flues we get a very safe and convenient form of boiler. If it can be shown, however, that quite as safe, and in other respects as good boilers can be made of a different form, then there is no reason why we should continue to make boilers in which there is useless surface. Within the last few years this truth has begun to be felt, although not expressed in quite the same way we speak of it. For exampie something has been done to utilize, the otherwise useless bottoms of Cornish boiler flues, by making them receive the lower ends of Galloway tubes. Again, the locomotive type of boiler, in which there is comparatively little useless surface, is growing in favor as a stationary steam generator. The same class of boiler is even beginning to find its way on board ship, and arrangements are being adopted now more than ever to render the otherwise useless surface of Lancashire boilers of effect. In these boilers the flame rushes straight to the back of the furnace and over the bridge, and some two feet or three feet in length of the front of the furnace crown is only of the least possible use as a steam generator. Experiments made to test this have been conclusive. By turning a brick arch inside the furnace some three feet long, measured from the fire-door, the steaming powers of boilers have been increased rather than diminished. Any expedient which will delay the flame in the furnace is of use, provided it does not interfere with the draught; and it is for this reason, no doubt, that a furnace which we illustrated last week has so far and experimentally given such good results. We may consider the whole question from another point of view. For example, if a flue or flues are longer than is necessary, then the extra length is useless; and this will be found to admit of some very important deductions.

If we take the case of a Lancashire boiler, with flues of any given length—say 30 feet—it will be seen on reflection that the first particles of heated gas which come in contact with the iron of the boiler beyond the bridge, part with their heat and become useless; but instead of being got rid of there and then, they are carried further mixed with other volumes of gas, which they tend to cool down. Thus at each foot of length of the flue there are no doubt to be found volumes of gas which have fallen, perhaps, from 2000° to 400°, and which are reheated to 1000°, and finally leave the boiler at 700° or 800°. Along the centre of the flue may proceed a column of gas which never comes into contact with the plates at all, unless some device be introduced, such as brick bridges or Galloway tubes, to break it up. In locomotive boilers, again, small as the tubes are by comparison, there can be no doubt that the products of combustion are discharged at a higher temperature than they need be, because molecules of gas which have already parted with their heat are mixed with hotter gas, and although they cool it down, the resulting mixture is discharged at a hotter temperature than each group of molecules which had actually touched the brass of the flue. The extension of surface required to carry away degraded products of combustion, as we may term them, with those not degraded may be regarded as more or less useless. To make our meaning clear, let us suppose that from a sewage carrier, branches diverged, in each of which was placed a filter. Then as the sewage flowed down the carrier a portion would turn off to a filter, become perfectly purified, and then return again to the sewage carrier lower down, when it would of course become again polluted, and unless it could be shown that the whole of the sewage passed through a filter, it is clear that at the last no absolutely pure water would be delivered into the river which ultimately received it, and this although portions of the sewage might have been clarified several times over. It is obvious that such a system is bad, and yet it is precisely analogous to that on which boilers are constructed. The proper principle contemplates the rapid cooling down of the products of combustion, and no subsequent reheating. This end could be secured in a boiler in which the tubes were extremely small, say only ½-inch in diameter; such a tube will have a cross section but one-sixteenth of a 2-inch tube, while its surface will be four times less. Consequently a tube of the small diameter and two feet long would be as efficient as a 2-inch tube eight feet long. The latter would, it is true, have a surface of in round numbers four square feet, while the other, the ½-inch tube, would have a surface of about one-fourth of a square foot. But the small tube would deliver the products of combustion which passed through it, cooler than would the 2-inch tube, and for this reason much less surface disposed in the shape of ½-inch tubes would suffice than would be required were 2-inch tubes to be retained. The practical advantages which might be gained in many instances by the use of excessively small tubes will be apparent without further explanation. By saving what is now useless surface, and retaining only surface eminently useful, the weight of a boiler would be much reduced, and its cost would not be seriously augmented.

In order that all boiler surface may be rendered as useful as possible it is essential that the escaping products of combustion should be split up into the thinnest possible filaments. Only those who have tried it can realize the promptitude with which furnace gases thus treated part with their heat to the water in a boiler. There are certain objections, however, to the use of very small tubes on the score of first cost, small calorimeter, &c., which hinder their employment. But these cannot be urged against the use of sheet flues—that is to say, flues taking the place of tubes. These, if made not more than one-half inch wide inside and but one foot long, will as effectually cool down a heated gas as the ten-foot two-inch tube of a locomotive. That such flues can be employed there is no room to doubt. Messrs. Day and Summers, of Southampton, used for many years with great success sheet flues less than two inches wide and about seven feet long by four feet deep. The introduction of high pressure stopped the extension of the system. We have no hesitation in saying that if any boiler engineer will take up the sheet-flue system where Messrs. Day and Summers left off, and push it to its legitimate end, a new class of steam generators can be produced which will be smaller, lighter, more powerful, and more economical than any that have gone before. There will be no useless surface about them. Only those who have seen a run of two feet or even less for hot gases, doing as much to cool them down as 100 feet of run in the case of a Lancashire boiler, or 10 feet run in a locomotive, will understand of what the further extension of the system of cutting up flame and gas currents into filaments is capable. It may be supposed that narrow spaces would quickly soot up. With a sharp draught—and all boilers on the system to which we allude must have a sharp draught—no sooting up will take place if good steam coal be used. For bituminous coals they are not suitable. We may add that so far as we are aware no patent stands in the way, and that it is open to any one who pleases to adopt the sheet flue system; and it is worth notice that vertical surface in these flues is just as good to all intents and purposes as horizontal surface. If an attempt be made to work with sheet flues more than half an inch wide inside disappointment will result. The essence of success lies in cutting the products of combustion into exceedingly thin slices, a layer of metal and a layer of gas turn about.

LIGHTNING CONDUCTORS.

From the "English Mechanic and World of Science."

There are many points upon which electricians do not agree among themselves, but perhaps no branch of their study has been the cause of so many conflicting opinions as lightning-conductors. If you find two electricians who agree as to the theory of the lightning-conductor, they will in all probability differ completely as to the manner of its application and the dimensions most suitable for a given purpose. The bibliography of the subject is extensive, and includes a number of papers from the most distinguished physicists of the present and the last century; but we doubt whether any practical information of much value is to be obtained by a perusal of the whole library, while the reader would certainly acquire a very confused notion of the subject unless he had already received a preliminary training in the principles. The author of the work before us seems to have felt the need of just such a book as he has produced, and his practical experience in planning out lightning-conductors has enabled him to produce a really useful guide to architects, clergymen, municipal officers, and others, upon whom may devolve the duty of protecting public and other buildings from injury by lightning. Mr. Anderson has not given us any pet hypothesis of his own as to the nature of lightning, but has judiciously consulted the works of the best authorities, and has furnished us with a readable history of the lightning-conductor, and probably a correct description of the nature of the effects it is intended to prevent. The practical part of the work is, however, the more valueable portion, as it supplies non-technical readers with information that many have desired to obtain. It commences with Chapter V., on Metals as Conductors of Electricity, in which the author has, rather uncharitably, exposed the liability of the most distinguished scientists to make serious errors. The relative conductivity of metals is known now-a-days with tolerable accuracy; but the figures given by such as Humphrey Davy, Becquerel, Ohm, Lenz, and Pouillet, are in some cases inexplicable. Davy taking copper as a standard at 100, found the conducting power of silver to be 109, and iron 14.6, while Becquerel, adopting the same standard, put silver at 73.5 and iron at 15.8, the comparative similarity in the one case making the discrepancy in the other all the more remarkable. The figures given by Lenz are, however, more noticeable still, for he found silver to have a conducting power of 136 and iron of 17.7, while as if to render the subject more mystifying still, Ohm rated silver at 35.6 and iron at 17.4. Pouillet's figures are: silver 81.3, iron between 15 and 18. It will be seen that while the five distinguished experimenters gave very varying results for silver, as indeed they did also for gold, the figures apportioned to iron agree in a very remarkable manner, and there can be no doubt that by taking iron at 16½ and copper at 100, we have a probably accurate estimate of the relative conductivity of the two metals best adapted for making lightning-conductors. In the chapter on the Character of Lightning and Thunderstorms, allusion is made to the statement that Solomon overlaid the Temple within and without with pure gold, and thus, unwittingly perhaps, took the best possible means of preserving the edifice from injury by lightning. According to Josephus, Solomon ordered the whole roof to be ornamented with sharply-pointed and thickly-gilded lancets of iron, presumably to prevent birds settling there and soiling the roof. That these points played an important part in protecting the building there can be little doubt, for all experience has indicated the use of points and large surfaces of metal in the attempt to protect buildings from lightning. The chapter on Inquiries into Lightning Protection is a useful, though necessarily brief, account of experiments and reports hitherto made with the view of obtaining some definite data upon which to work, and that it is followed by a chapter recounting the experiments of Sir W. S. Harris. It is not impossible that more has been learnt from the failures of conductors than from a study of the theory of lightning, and there can be little doubt that copper is, all things considered, the best material for conductors. The remarkable discrepancies in the conductive power of metals alluded to above were, in all probability, mainly due to the use of impure samples, for Prof. Matthiessen found that if pure copper were taken as standard 100, best American would be only 92.5; Australian, 88.8; Russian, 59.3; and Spanish Rio Tinto only 14.24. Objections were formerly urged against copper on account of its expense; but a more potent reason for its neglect was the simple fact that a suitable copper conductor could not have been obtained. It is essential that the copper should be as pure as possible, for as it is six or seven times the price of iron, it is advisable to take full advantage of the greater conductive power of the more costly metal, which it will be seen nearly balances the difference in price. So far it may be said that iron and copper are practically equal, but there are two other points to consider, and in both of these copper is by a very long way the superior of iron, viz: durability and flexibility. We can readily agree with Mr. Anderson, then, that copper is the best material for a lightning conductor, and it is not impossible that the wire ropes made by Newall & Co., which have, we believe, a guaranteed conductivity of 93 per cent. of pure copper, are the most suitable things in the market. Chapter X. describes what has been done at the Hotel de Ville, Brussels, and at Westminster Palace, the former building being probably the best protected of any in the world. It is covered on a plan devised by Professor Melsens, consisting of a perfect net-work of metal, with numerous points and ample and perfect earth-contacts. The descriptions of the measures taken to protect these buildings will serve to show what is considered good practice, and the practical details under the head of weathercocks, and descriptive of practice in France and America, will help to make the subject clear. The chapter devoted to an explanation of Newall's system is, however, an epitome of the whole subject, and as numerous examples are given, the reader perceives clearly what is required for a barn, a house, a factory chimney or a church steeple. The system advocated by Melsens, of many small rods, instead of one large one as adopted by Mr. Anderson, but it is tolerably well understood now-a-days that advantage should be taken of the presence of any considerable piece of metal in a building to bring it into the circuit of the conductor. Thus a church, for instance, instead of ridge tiles should preferably have a ridge of iron, which could be connected to the conductor, and so save the expense of running a copper rope from end to end. Several illustrations of the arrangement best adapted to special cases are given by the author, who also gives particulars of such minor details as fastenings, which should preferably be copper clamps built into the wall, in the case of a chimney for instance, though simple staples nailed to the wall will do very well in the case of the smaller and lighter conductors employed on houses. Not the least interesting portion of the book are the illustrations of the effects of lightning as seen in the case of churches and other buildings that have been injured by lightning, an engraving of the monument to General Baird, on the summit of Tomachaistle, near Crieff, serving as a frontispiece, and an excellent example of the disruptive power of a lightning stroke. The "earth connection," very appropriately, has a whole chapter to its consideration, and there are several engravings showing the most approved methods of insuring that at all times the earth wires shall be capable of distributing the discharge. A chapter urging the necessity for frequent inspection and testing of all lightning-conductors, brings the work to a close—a very full bibliography forming an appropriate appendix. The book is well printed on good paper, and will, no doubt, become the standard text-book for use by those who are engaged in erecting lightning-conductors,

Manufacture and Melting of Iron and Steel.—In the ordinary method of manufacturing iron the blast-furnace in which the iron ore is reduced is urged by a blast of atmospheric air. A blast of atmospheric air is also employed in the treating of iron by the Bessemer process for the production of steel, as well as in cupolas and refineries in which iron is melted for casting and for refining. The blast employed is drawn direct from the atmosphere, and contains a greater or less amount of the vapor of water varying with the hygrometrical condition of the atmosphere from time to time. This vapor of water undergoes decomposition in the furnace, causing an absorption and loss of heat therein, varying from time to time in proportion to the greater or less amount of vapor thus introduced into the blast. The hydrogen evolved by the decomposition referred to gives a porosity to the iron or steel under treatment, which is very injurious in castings.

In order to prevent the loss of heat referred to, and thus to economize the fuel employed, and promote rapidity of fusion and a regular working of the furnace, and also to prevent to a greater or less extent the porosity produced in the iron or steel made or melted with air containing vapor of water, Mr. W. H. Fryer, M. E., of Coleford, Forest of Dean, proposes the desiccation of the blast. He passes the air to be forced into the furnace, cupola, or refinery, or Bessemer convertor, through or over sulphuric acid, or chloride of calcium, or other desiccating material, so as to deprive the said air wholly or in great part of the vapor of water contained in it. The desiccating material may be disposed in various ways in a chamber or receptacle through which the air is passed, the particular arrangement depending upon the nature of the material employed (whether solid or liquid) and its desiccating and other properties, the essential conditions of the arrangement of the said material and chamber or receptacle being that the desiccating material shall expose a larger surface to the air, and that the capacity of the chamber or receptacle shall be such that the air will travel through it at a sufficiently slow rate to ensure the thorough action of the desiccating material upon it. The desiccating material may be either supplied continuously or renewed from time to time as occasion requires, the particular arrangement for supplying and renewing the same depending upon the nature of the material (whether solid or liquid) and its desiccating and other properties, and the mode of restoring its efficiency when lost by use. Although the invention is principally applicable to furnaces used in the manufacture of iron and steel, and through which air is urged by a blast, yet it may also be applied to furnaces through which the current of air for maintaining combustion is drawn by an exhaustion, whether the said exhaustion be produced by a steam or other motive power engine, or by the draught of the heated and rarefied air in the chimney stack.—*Mining Journal.*

THE PATENT LAWS AND THE PATENT OFFICE.

By JAMES A. WHITNEY, Counselor-at-Law.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

THE promotion of industries is the source of national wealth. The prosperity of all modern nations is due to a recognition of this truism. And among all the means for insuring the development of useful arts and the extension of commerce, there are none that have been more efficient than the system of protecting inventors, during limited periods, in the enjoyment of the fruits of their intellectual work. The reason of this is manifest. If the result of a given amount of labor on the part of an individual be multiplied ten-fold, the value of that individual to the community is increased in a like ratio. The same result is obtained as concerns communities, for if a city, state or nation, is enabled to multiply the results of its labor, in proportion to the number of its population, its importance in the great family of nations is proportionately greater. And if we extend the principle to embrace the various countries of the world, we find the result to be simply this, that the capacity for production being extended, the supply, to meet the wants of humanity, is correspondingly promoted. Hence it is that the comforts of life at the present time are far greater, and far more easily obtained for all classes and grades of society than they were two hundred and fifty years ago. We have only to adopt Macaulay's comparison of the condition of the English people in the time of Elizabeth with that of the time in which he wrote, a third of a century since, to perceive to what an extent the adoption of inventions—or as they are technically termed improvements in the useful arts—have ameliorated the condition of the human race. It is true that the development of industries cannot be traced to any single source; and it is true also that natural causes as well as legislation have contributed directly or indirectly to the results just indicated; but it is equally true that no single agency has equaled in efficiency, or in the magnitude of its fruits, the system of granting letters patent for inventions as an incentive to the production and application to use of practical improvements.

As relates to the history of the system, its inception can scarcely be traced. Something of the kind, as we are told by Montesquieu, held an important place among the land laws of the ancient Persians, and conduced in no small degree to the reclamation of the sandy wastes between the Euphrates and the Tigris. Something similar in principle existed among the Romans in the usage, which protected orators against the illicit reproduction of their manuscripts. In Europe, as concerns industrial arts, the first instance of which we have knowledge was in the latter part of the fifteenth century, and related to the new practice of an old art, that of manufacturing saltpetre, rather than to the practice of a new invention.

Patents were granted in Nuremberg during the period of the Renaissance, and in England for the first time in the reign of Edward III., and curiously enough for the production of the Philosophers' stone, the possibility of the transmutation of metals being then a matter of universal belief. The first fruits of the system, however, appeared on the continent, and through the encouragements thus given, the manufacturers of Flanders, France, and some parts of Germany reached a high state of excellence in their work and products, which latter found a ready market in England. From this arose what may be termed the inception of the middle classes of Great Britain, a mercantile and trading class as distinguished from the warlike barons on one hand, and their servitors on the other. It was this class that really turned the scale in the wars of the Roses in favor of Edward IV, for had it not been for the support of the trading community, the defeat on Barnet-field, of Warwick the king-maker, at whose tables thirty thousand fighting men are said to have sat at meat, would have been impossible. The protection of industries on the continent, therefore, led to the full development of the commercial spirit in England, and this, in its turn, produced a condition of society favorable to the next advance, that of the permanent planting of manufactures on British soil, whence, after long lapse of time, they extended to our own country. It was during the period between the reign of Edward IV and that of James I, that the protection of new inventions by letters patent grew up side by side with a quite different one, the mischievous system of monopolies, which, although of quite opposite character, has often been confused with patents granted for meritorious inventions. The difference, however, is plain, when we consider that an invention is something new, something that the public has never possessed before, something that is an addition to the previously existing property and knowledge in the world; whereas a monopoly in its widest sense is something taken from the public, and given over to the benefit of the few. New inventions, by adding to the resources of labor increase wealth, and promote comfort, while monopolies in articles previously in general use, by restricting the exercise of known arts, are full of harm to all except the monopolists themselves.

During the period last referred to the tares grew quicker and higher than the wheat; so that the protection of new inventions was overshadowed by the creation of monopolies which at last grew to be a bitter grievance and a hindrance to the national growth. It was this which produced the great revolution, and in the famous statute of monopolies in the 21st year of James I, A. D. 1623, the line was distinctly drawn between meritorious letters patent, which are advantageous to the growth of industries, and the harmful exclusion of the public from the practice of trades, occupations, or branches of business, that are part of the common inheritance of the people. This celebrated statute forbade monopolies, but expressly permitted the granting of letters patent: for any new manufacture within the realm was specifically excepted, and left unharmed. It is to this period that the text writers refer the origin of patent laws, but as a matter of fact this statute created no new protection for inventors, for as concerned *bona fide* inventors it left the matter as it had been from an unknown date in the administration of English law, and no material change was made for more than two hundred years, except in so far as the courts construed and elaborated the meaning of the terms employed in the statute of monopolies.

Our own country derived the system from England, each colonial government having the right to issue patents within its own jurisdiction in the same manner as they were issued in England, although the English government in some cases, issued patents that included both England and the colonies. After the establishment of our independence, the states continued to exercise this power within their own borders, and it was in this way that the State of Maryland accorded to James Rumsey, the exclusive privilege of making and selling "newly invented boats of a model by him invented," in the year 1785; and Fulton owed his financial success to a similar patent granted by the State of New York. In the year 1790, Congress passed a general patent law, the effect of which was to transfer the administration of the system entirely to the General Government, it being provided that no patent should issue under the act, on any invention which was the subject of a patent from any state. This, therefore, was the beginning of the present or Federal patent system of the United States. But the administration of the system has been from the first modeled upon the practice and precedents laid down by the English courts before the date last mentioned. British decisions during the latter part of the eighteenth century, and notably the *causés celèbre* of the *King* vs. *Arkwright; Watt* vs. *Hornblower*, and several others, elaborated the ethics and applications of the law, into a complete and rounded system. It is to Judge Story, who followed closely the precedents of English jurists, that the credit belongs of molding the American law of patents into consistency and shape.

The patent law proceeds primarily upon the fact, that improvements which increase the result of human labor or multiply the fruits of industry are advantageous to civilization, and beneficial to the community at large. It, therefore, becomes necessary to offer a premium to genius and skill for the production of the desired improvements. And of all methods that have been attempted, experience has decided that there are none so simple, so manifestly equitable, and so convenient in actual practice as that of permitting the inventor to appropriate to himself the profits of the invention, during a certain limited time, upon the express condition that he disclose his improvement to the public in such shape and in such a manner, that after his peiod of exclusive use has expired, the public will be enabled to put it in operation. This is the principle of the law of patents, and it rests upon the same ethical ideas as the law of contracts. The exclusive privilege is given in payment for an invention to be dedicated to the public at the end of a certain specified time. All that the inventor can gain from it during that time is his, while to the public belongs all that the public can gain from it in all the ages after. But while this is the principle of the law, and its result as well, there is still another advantage to the public in the fact that the placing of a new improvement in the market, or adding a new invention to the resources of any branch of industry, even while under the absolute control of the inventor, is itself an immediate gain to the community, for the manifest reason that the community will not adopt the improvement or enable it to afford profit to the patenee, unless it can itself gain by so doing.

The principle of the law being thus stated, it is of interest to consider its administration. In order to provide for the granting of patents under suitable guarantees, or rather under suitable assurance of novelty and utility, the Government has organized a special bureau charged with the examination of every application, and the issue of every patent when its subject matter is found to be new and useful. This bureau, under the charge of the Commissioner of Patents, forms a part of the Interior Department, the Secretary of the Interior being invested with general jurisdiction over the Patent Office. There is, in addition to the Commissioner, an Assistant Commissioner and a Board of Examiners-in-Chief, comprising three judges, at the present time acute and experienced judicial officers whose decisions are frequently models of close and accurate reasoning, characterized by a clear appreciation of the true spirit and intent of the patent laws. The examining corps proper consists of principal Examiners together, with first, second and third assistant examiners. There is, in addition, a special Examiner of Interferences, and a large force, many of whom are ladies, devoted to the clerical work of the office. It will be seen that the organization is necessarily complex, and that its magnitude is considerable. The com plexity would be obviated, and the work of the office would be much better performed, if the working force was increased, and excessive labor was not required from officials, who, as a rule, earnest, industrious, and efficient, have long been over-burdened and underpaid. In other words, a more numerous force, and better pay would render of easy attainment, an excellence of administration that is now impossible.

The several steps necessary to obtain a patent may be briefly stated as follows: There must, in general, be provided a model, which should be of substantial material. The invention must be represented by drawings where such are possible, and these should show the invention clearly and in detail, and must be of a character which will permit them to be photo-lithographed. A description of the invention, which, with the drawing, constitutes the specification must also be filed, and must contain a clear and condensed description of the improvement. It must also clearly state the parts or combinations that are claimed to be new, and as a rule must embody a brief statement of the previous state of the art to which the invention relates. It frequently happens that an invention is found to be anticipated in part, and in such cases an amendment, properly drawn to cover what is new and to exclude what is old, must be filed before the case can be passed to issue. Of course if the invention is found to be wholly anticipated by some anterior invention or by something so nearly like it that nothing more than mechanical judgment is required to make the old device equal to the new one, the application is rejected. On the filing of each application, a government fee of fifteen dollars is required to be paid, and an additional fee of twenty dollars before the patent is issued.

The time required to obtain a patent after the papers are filed, varies according to circumstances. If the application is properly prepared in the first instance, and the invention is not anticipated in any of its essentials, the allowance will depend simply upon the condition of work before the examiner to whom it passes for examination; and this may be from two weeks to two months. Some classes of invention are so complex that the examiners are necessarily behind with their work, so that the cases being taken up in their order of filing are always more or less delayed; while in others it is possible for the examiners to keep the work so closely in hand that but a few days are required between the filing of a case and its allowance. If, however, by reason of partial anticipation of the invention, or other causes, amendment is necessary, further delay is caused, and the progress towards issue in such instances depends upon the diligence of the applicant or his attorney, and upon the skill displayed in so framing his papers as to place the case accurately and clearly before the examiner. Sometimes where an interference is declared, the delay may be extended to several months, the time being required for the taking of testimony, the making of motions, and other proceedings necessary in arriving at a judicial decision on the merits.

Assuming the specification, drawings and model to have been properly prepared, and the petition, etc., to be in due form, the course of an application in the Patent Office is as follows: The model goes to the machinist, whose business it is to ascertain if it be of proper size and finish, and of substantial make. The specifications go to an official of long experience, who looks to the regularity of the papers, but without examination of the contents of the specification; while the drawings are sent to the draughtsman who examines them as to their size, legibility and fitness for lithographing. In the meantime, the fee of fifteen dollars is paid into the office of the chief clerk. The model, drawings and specification, together with the petition and affidavit attached, are then assembled and sent to the examiner to whose class the case belongs, and by him it is taken up for examination in its course. The preliminary work of examination is commonly done by an assistant examiner, each principal examiner being held responsible for the work done in his room. If an application is rejected, the applicant is entitled to a re-hearing before the principal examiner; if the latter persists in his rejection an appeal lies to the Board of Examiners-in-Chief. If the case be still rejected by this tribunal an appeal lies to the Commissioner in person, or in his absence to the Assistant Commissioner, as acting commissioner, or, when the applicant consents, before the Assistant Commissioner, in his capacity as such. If the case is still rejected and the applicant is satisfied that he yet has grounds for a further appeal, such may be taken to the Supreme Court of the District of Columbia. The government fees required by these appeals are ten dollars when the appeal is to the Examiners-in-Chief, twenty dollars when to the commissioner, and ten dollars when to the Supreme Court of the district. In cases where the patentability *per se* of the invention is admitted, but the invention is claimed by two or more different parties, an interference becomes necessary. The proceedings in such cases resemble those of an action in equity. Apart from special motions (which at certain stages may be made and tried before the principal examiner, the Examiner of Interferences or the Commissioner in person, according to the state of the case), the hearings are as follows: First, before the Examiner of Interferences; second, on appeal before the Board of Examiners-in-Chief, and third, on appeal to the Commissioner. In interference cases there is no direct appeal from the commissioner to the Supreme Court of the district as in *ex parte* applications, but a separate action in equity may be maintained even after a patent has been issued in accordance with the decision of the Patent Office.

It will be seen from the foregoing that the proper prosecution of cases before the Patent Office is a matter of some complexity, and involves no slight degree of professional judgment, skill and care, and that the duties of the Patent Office are onerous and responsible to the last degree. On this last mentioned point it may be justly said that more of the complaints that have been made against the general efficiency of the Patent Office have arisen from misapprehension of the character of the duties required of the officials, and of the skilled professional labor necessarily called for in the preparation and prosecution of cases, than from any actual mal-administration within the Patent Office. While undoubtedly instances sometimes arise where individual examiners through carelessness, lack of experience, or native perversity of temper, work injustice or annoyance to an applicant; such are not common nor are they to be taken as fair examples. There is probably no department of the government where high acquirements and uniform courtesy are more imperatively demanded or more fully displayed than in the administration, and by the officials, of the United States Patent Office. And while, as I have said, occasional instances arise where complaint may be justly made, yet these are probably few as compared with cases where incompetent attorneys have been helped out of their difficulties by the courteous, though extra-official suggestions of examiners. This last, however, although in motive creditable to the examiners, is productive of evil by encouraging the slovenly preparation of applications, and by enabling persons comparatively incompetent to persist before the office in the *role* of attorneys. The result in such cases is to shift the duties of the attorney upon the examiner, who is employed and paid by the Government, not to prepare applications or amendments, but to act considerately and justly upon them after they have been duly filed.

In another respect, however, there is a just cause of complaint, not against the Patent Office, but against the parsimony of the Government, which keeps locked up in the treasury nearly a million of dollars drawn from the resources of the Patent Office, instead of devoting it to the enlargement of the latter and the increase of the means for the proper transaction of business. Since the re-organization of the Patent Office in 1836, salaries of officials in every other branch of the government have been materially increased, but in so far as concerns the Patent Office, they remain substantially the same. And this, too, notwithstanding the fact that the intricacy and multiplicity of the duties of the Patent Office is much greater now than then. The bureau is inordinately cramped for room. It is keeping within bounds to say that ordinarily six persons, examiners, copyists, etc., work in a room of a size not more than sufficient for the comfort and convenience of three. The exacting labor of some of the most important classes is carried on in apartments originally designed, it is said, for coal bunkers, and in which the moisture creeping through the walls brings discomfort, if not illness, to the occupants. This and many other drawbacks to the perfect working of the Patent Office could be remedied by wise legislation and a judicious use of money that should be devoted to the purpose. It is well, while waiting for the slow evolution of a public opinion which shall compel a just consideration of the deserts of this bureau, that the community at large should apprehend to what extent the Patent Office is compelled to make the best of very untoward circumstances. Speaking from my own observation, during years of professional practice before the department, I can truly say that I do not believe that any other body of men have performed duties equally onerous in a more conscientious manner, or for smaller remuneration both of money and popular appreciation, than have the officials of the United States Patent Office.

In coloring and lacquering brass work, browns of all shades are obtained by immersion in a solution of nitrate or the perchloride of iron, the strength of the solution determining the depth of the color. Violets are produced by dipping in a solution of chloride of antimony. Chocolate is obtained by burning on the surface of the brass moist red oxide of iron, and polished with a very small quantity of blacklead. Olive green results from making the surface black by means of a solution of iron and arsenic in muriatic acid, polished with a blacklead brush, and coating it, when warm, with a lacquer composed of one part lac varnish, four of tumeric, and one of gamboge.

THE STEAM ENGINE OF THE FUTURE.

By JOHN BOURNE, C. E.

In all human affairs an insight into the future can best be obtained from an intelligent review of the past. The lines along which improvement has advanced in former times will also be those through which it will flow in times to come, for the continuity of the grooves in which the motive forces act is not broken by the horizon of the Present, but, on the contrary, extends into the Future with the certainty of inexorable law. The direction of these hidden prolongations, moreover, can be approximately determined by observing the routes followed in that part of the course which, having been already completed, is clearly in sight, and the laws which govern the advance, and which act alike in the past and in the future, are thus rendered discoverable. It is from the aid rendered by this method of research that I am enabled to speak of the "Steam Engine of the Future" with warrantable confidence, as such future stands as plainly revealed to me as if it had already passed into the attestations of history.

It is now more than thirty years since my "Treatise on the Steam Engine" was published. Of course, before writing that work I had to study the subject, and many years of antecedent experience were given in its pages. I can therefore, I believe, without arrogance claim to have had as prolonged and as intimate an acquaintance with the steam engine in its various phases as any person now living; and if this be so I am entitled to speak with corresponding confidence of the present condition and future prospects of that great instrument of civilization. When I began to write the class of small engines, now applied to the operations of agriculture and to the multifarious uses of the arts, hardly existed at all; and the knowledge of the steam engine was confined to a narrow circle and was jealously guarded. I believe that I was mainly instrumental in throwing open the portals of this technical empyrean; and a little before the date of the first Exhibition small engineering factories, profiting by the information thus placed within their reach, began to spring up in considerable numbers. Blacksmiths and agricultural implement makers rapidly expanded into full-blown engineers; and in many cases the want of skill in their productions was little redeemed by fastidious modesty in their pretensions. At first the demand for small engines for miscellaneous purposes was not very great. But it has gone on increasing at an accelerated pace; and, notwithstanding their existing imperfections, small engines of different kinds are now produced to the extent of some hundreds of thousands yearly. The demand, too, it is quite clear, is still in its infancy, and will rapidly swell into more imposing dimensions than have yet been anticipated by even the most sanguine mind. There are various causes for this, which it will not be difficult to specify. In the first place, the natural increase due to the known acceleration in the rate of the demand will necessarily be large. But new and more extended fields of activity are fast opening up. Thus, in works and factories of every kind it is the impending tendency to split up the large central engine which has been heretofore in use into a number of small engines, placed in convenient situations about the works. A central engine, transmitting its motion to distant points by means of shafting, expends a large proportion of its power in friction; and if any portion of the engine or of its gearing should be accidentally disabled the whole establishment is brought to a stop. By substituting several small engines for one great one there is less waste of power from friction; shafting is saved; and should any accident happen to one of the small engines only a part of the works is stopped, and comparatively little inconvenience ensues. In all new factories several small engines instead of one large one is now accounted the preferable arrangement for supplying the motive-power, and even in existing factories the replacement of the great lethargic engine of the old type by several small high-speed engines has already begun. In this inevitable substitution there is a new source of demand for small engines, which, in the future will rapidly become extensive, though in the past it has been but little felt.

Some years ago I was induced by a friend to become a director in an iron company which had large works in Wales. The machinery I found to be of antiquated pattern. There were two separate rolling works, in each of which there was a great central engine, driving rows of mills right and left for puddle-bars, for rails, plates, &c. The shafting was carried in a tunnel underground, and the motion was communicated from the engine to the shafting by an aggregation of toothed wheels, which also drove a great flywheel moving at a high velocity. I scarcely ever visited these works that I did not find some part of the machinery broken down. If the feed of the rolls were accidentally made too rapid, or the iron during the rolling became, from want of steam or otherwise, too cold, then, the motion of the rolls being resisted, while the great flywheel could not be suddenly arrested, the intermediate gear gave way, the whole of the mills were stopped, the half-puddled iron had to be withdrawn from the furnaces, and the men were thrown idle until a repair could be effected. On applying the indicator to the engine I found that there was not very much difference in the amount of power consumed, whether the mills were rolling iron or not, the larger part of the power being, in fact, wasted upon the friction of the shafting. I recommended that the shafting and gearing should be discarded, and that a separate small engine should be applied direct to every mill. This recommendation was adopted by the directors, but was objected to by the proprietors. The directors resigned, and successors, who had dissented from our policy in this matter, were appointed. But the penalty inseparable from a defiance of natural law soon followed. The works had to be discontinued, and the company was broken up.

Another considerable increase in the demand for small engines impends from the prevalence of the system of compounding. In cotton mills and other factories possessing old-fashioned engines, working with a low pressure of steam, it has for a number of years been a common practice, when new boilers were introduced, to make them capable of withstanding a higher pressure. A high-pressure cylinder was at the same time added to the old engine, and the steam was first used in the high-pressure cylinder, whence it was dismissed into the low-pressure cylinder in the manner of compound engines. By this arrangement the steam can be made to do double duty, and the power can be produced with half the coal. The system, however, as hitherto carried out is subject to several drawbacks. The application of another cylinder to the existing engine involves the stoppage of the works until the new cylinder and its gear can be fitted. The parts of the old engine are generally too weak to be capable of transmitting the increased strain without the risk of fracture, so that sundry new parts have to be substituted; and, as the piston of the new cylinder must move synchronously with the piston of the old, the motion is slow, and the new cylinder and its connections are consequently both large and costly. It has been pointed out by me that, instead of compounding, as it is called, in this clumsy fashion, the same end could be more easily and inexpensively attained by introducing a high-pressure high-speed engine into any convenient part of the mill or factory, and coupling this engine by means of a belt to any convenient shaft running at a high speed, the educted steam being led by a pipe to the old engine to work it. The new engine, as thus applied, might be quite small, and its introduction would not involve any stoppage of the works. There is no doubt that this is the method of compounding which will henceforth prevail, and a very considerable demand for small engines will spring up to enable the system of compounding to be thus applied.

Another new source of demand for small engines, more important probably than either of the foregoing, is opened by the introduction of the electric light. It appears now to be almost certain that electric lighting will, within a few years, supersede to a great extent the modes of lighting heretofore in use. The most economical source of the electricity required for this purpose is the steam engine; and, as the electricity cannot be conducted without serious loss through any considerable distance, it cannot be distributed like gas from a great central works, but must be produced by small engines at a number of independent centres. This new field for the steam engine promises to become one of great extent. But, in common with the indications in the other cases mentioned, the additional power is required, not in the form of a moderate number of very large engines, but in the form of a very great number of small engines moving at a high speed. In considering the probable extent of the conquests to be achieved by the steam engine in the future it is necessary to have regard, not so much to the condition in which that great instrument now is, as to the condition to which, under the influence of causes already in operation, it may reasonably be expected to ascend. The small engines at present offered for sale are often very defective; they are heterogeneous in design, and reveal in many cases conspicuous mechanical incapacity, and are generally produced under circumstances which hinder the combination of excellence with cheapness. In the interest of the public the desideratum manifestly is to have the most perfect possible design settled by the most competent existing authority, and to have engines on that plan, and that only, manufactured by special tools, without hand labor, whereby the greatest accuracy of production is insured at the minimum of cost. The mechanician who made for the Government the first of the army rifles now in use informs me that its cost to him was £62. It was made with the aid of the tools usual in engineers' workshops; and another example made in one of the Government workshops cost about the same sum. With the aid of special tools, however, in a factory erected for the purpose, the same rifles are now made for *fifty shillings* each.

The arrangements which cheapen rifles will also cheapen steam engines. But before such arrangements can be carried out the engines must be made in quantity, on a uniform plan, from which no departure can be permitted, aud the parts of each class of engine must be interchangeable. Small engines are now generally made of divers forms, with little skill, in limited numbers, at different small workshops scattered throughout the country, without the aid of those complete arrangements which are necessary for really cheap and accurate production. Even with such drawbacks, implying in most cases a low quality and a high price, the demand for these engines has rapidly increased. What, then, would the demand have been if all the desiderata known to be attainable had been utilized and combined?

But who is to prescribe the type of the small steam engine of the future? It is obvious to everyone that it is desirable, in the interest of the public, that the best type should be selected, and that *it* only should be made, for thus alone can the factory system be applied to the manufacture, and thus also can the public be most readily educated in the management of engines, as they are enabled to escape the perplexities incidental to heterogeneous forms. But how, it will be asked, is any general agreement to be arrived at as to the type of engine that is the best? To this the answer is, that the preponderance of opinion which has to determine this point must be informed and competent opinion, and that the light thrown on the future by the experience of the past gives an unerring clue to the solution of the problem. The limiting considerations on every side which will thus be made manifest will fix the main outlines of the design beyond the power of cavil to contest, and will guide public opinion to the selection of that type that will soon swallow up all the rest.

Thirty years ago I predicted that all rotative engines would become high-speed engines—a prediction which experience, so far as it has gone, has amply confirmed. There were difficulties, no doubt, in the way of this acceleration, but these were clearly superable, and the benefits resulting from the employment of a high speed were so numerous and momentous that it was easy to foresee that nothing could prevent the general introduction of the principle. I had a small engine constructed to ascertain the limit of speed which was feasible with engines of ordinary construction, and I found that when this small engine was run at a very high speed it shook the whole house, and the people in the neighbouring house sent in to ascertain what we were about, as the engine shook their house also. This tremor was obviously caused by the unbalanced momentum of the reciprocating parts of the engine, and the remedy for it was not difficult of perception. But about this time I was called to India in connexion with the introduction of the railway system into that country, and I had no opportunity of resuming the consideration of the subject till some years afterwards. On my return I constructed some screw vessels which were fitted with direct-acting engines, and which were intended to maintain a high speed. At that time screw vessels were generally fitted with gearing, by which the required velocity of rotation of the screw was maintained while the engines moved at the same slow rate which had hitherto been usual in engines of every kind. With the high speed of engine I employed it became necessary to balance the momentum of the reciprocating parts, which was done by applying counter-weights to the crank, so that when the piston and its connexions moved in one direction the counter-weights moved in the opposite direction, and thus took all shock off the shaft. This contrivance, which has since been very widely introduced in large engines of the best class, I patented, and its use is indispensable to enable steam engines to work smoothly at a high rate of speed.

In accordance with my anticipation, gearing in steam vessels is now completely discarded, and the engine is coupled immediately to the propeller. The benefits of this arrangement are too conspicuous to require much exposition. Not only is the noise and complication of the gearing avoided, but, as an engine with any given pressure of steam will generate a given amount of power at each stroke, whether the strokes per minute be many or few, it is clear that the amount of power generated by a given engine in a given time will be in the simple ratio of its velocity, and hence a given power may be generated with less first cost, with less weight of metal, and with less space occupied, by a fast engine than by a slow one. Of course the fast engine must be suitably constructed to be able to run with impunity at the high speed, to which end not only must the momentum be balanced, but the bearings must be of special metal and have a larger amount of surface than sufficed in the old slow engines. But these adaptations create no difficulty, and steam vessels with balanced high-speed engines, working day and night for weeks consecutively without any stoppage or difficulty, are now plying to all parts of the world. These engines are quite as durable as the old slow engines, and much more economical in fuel. It may be taken as an axiom in steam engineering that whatever is feasible at sea is certainly feasible on land, for the more difficult problem comprehends the more easy.

The benefit of working steam engines expansively is well known to engineers, as also the necessity of employing a steam jacket in engines so worked, to obtain the full benefit of the expansive principle. It is not generally known, but is nevertheless the fact, that in high-speed engines there is a further benefit arising from the inability of the cylinder to become sensibly heated and cooled at each stroke, from the shortness of the time given for that process, and in such engines the cylinder approaches to the condition of a non-conductor, which is known to be favorable to the economical generation of power. Then, in the case of all high-pressure engines, it is easy to see that a considerable pressure must be more beneficial than a lower pressure. To raise a given quantity of water into steam takes just the same quantity of heat, whether the evaporation is effected at the pressure of the atmosphere or at six or eight times that pressure. But at the low pressure the steam will not generate any power, whereas at the high pressure it will generate much power. A very high pressure of steam, however, is inconvenient, as it involves a correspondingly strong and heavy boiler, an extra strong and heavy engine, and separate expansion gear, which is not compensated by the small amount of increased economy obtained from excessive pressure. I have found a pressure of about eight atmospheres to be, on the whole, the most eligible that can be adopted.

I propose to limit this review to the case of small high-pressure land engines, and the principles which have been enunciated will indicate pretty clearly the main characteristics which must distinguish such engines in the future. First of all, they must be *high-speed* engines. Next, they must have the momentum of the reciprocating parts *balanced* by counter-weights. They must be supplied with steam of considerable pressure, worked expansively, and the cylinder must be steam-jacketed and lagged. They must obviously be both light and strong, compact in form, simple in construction, and with all the parts easily accessible; and they must also be self-contained, so that an engine may be lifted in a piece and be worked in either a horizontal position, on a separate pedestal, or placed vertically against a wall or the side of a vertical boiler, as circumstances may render advisable. Of course means of efficient lubrication must be provided. These several indications in 1870 I embodied in the design of an engine constructed for me at that time by Messrs. John Penn & Sons, and in settling the details of which I had the advantage of their assistance. This engine, of which detailed drawings appeared in my recent work on "Steam Air and Gas Engines," and which is represented in the annexed cut, is now employed in generating the electricity for the electric light at the Polytechnic Institution, in Regent street. But although this and other similar examples constituted a great advance upon pre-existing designs, these early engines were by no means free from faults, which have only been eliminated by degrees, and an improved type, divested of these faults, has thus been gradually evolved in the course of years. There is no such thing as finality in steam-engine improvement. But a stage of ascertained efficiency has now been reached which, I think, warrants production being expanded into manufacture. I had hopes of being able to induce Messrs. Penn & Sons to engage in such a manufacture. But as they have not found this compatible with their other occupations, it is now proposed to erect a special establishment for the purpose. The time has at length arrived at which some step of the kind is indispensable. High-speed engines require to be specially well made, with special materials and special skill. Without special tools good work is costly. But with them good work is as cheap as bad.

Supposing a good and cheap small engine to be available—an engine that will be strong, simple, safe, light, noiseless, and economical in fuel—not only would all its industrial applications be extended, but it would find a new and wide sphere of usefulness in ministering to domestic wants, one of the most widely pervading of which is the want of a simple motive-power. In American hotels steam engines have long been employed for brushing boots and cleaning knives. They are the docile and inexpensive Helots of the age, and the domestic production of the electric light is a new and important sphere for their energies. But besides these functions a domestic engine may be employed in roasting meat, driving washing machines and mangles, driving sewing machines, in brushing hair, in preparing aerated waters, and in the country for pumping, for sawing wood, and for performing many other laborious operations. A steam engine may be made to cool houses in summer and to warm them in winter, to maintain fountains in conservatories, to work punkahs, to produce ice, and to create and maintain a vacuum in safes for the preservation of meat. For such purposes the engine must obviously be of the simplest, most compact, and most inexpensive character, and should be attached to the boiler, so that the whole may be lifted in a piece, like a hall stove. The boiler should be provided with a self-acting feed of water, and the fuel should be gas, which has only to be lighted to enable the engine to be put into operation. Gas companies will find ample compensation for the loss of their lighting function in the creation of a new heating function, which will become larger and more remunerative than the lighting has ever been. Instead of extracting from the coal only the illuminating gases, the whole fuel should be turned into combustible gas by the aid of superheated steam, and all the fires of houses could be maintained by this cheap gas burning in jets amid pumice, which it would keep red-hot. There would then be neither dust from grates nor smoke from chimneys, and the gas works would supply the fuel that is necessary for the generation of the electric light.

I cannot pretend in this brief notice to enumerate all the improvements which the steam engine of the future should comprehend. But one essential quality is, that the boiler shall not be liable to internal incrustation, and that there shall be abundant facilities for easily cleaning it out. Most waters contain a certain proportion of lime, which is precipitated by boiling, and in tea-kettles this lime forms an internal crust, which is termed "rock." Such incrustation hinders the transmission of heat through the metal of a boiler, and is injurious in various ways. But there are known means of preventing its formation, and in the "steam engine of the future" it is an indispensable feature that these means shall be embodied.

The application of the steam engine to the propulsion of carriages, omnibuses, and cabs is now only hindered by its too heavy weight and too high cost. Asphalte pavements, which are objectionable for horses, afford for steam carriages a surface as eligible for easy traction as a railway, and without any countervailing fault. All wheeled vehicles, whether required to travel at a high or at a low speed, will be propelled by steam instead of horses as soon as the steam engine is made sufficiently light and sufficiently cheap to warrant the substitution. Lifeboats, instead of being open boats propelled by a number of men, should be decked boats propelled by a steam engine, and managed by only two men, one to steer the boat and the other to attend to the engine. Such boats should be propelled by a water-jet which will always act, whatever may be the roughness of the sea, and whether the stern of the boat is in or out of the water. The use of the steam engine for irrigation in connection with the centrifugal pump is an application of which the sphere is limited only by the cost and the deficient portability of the apparatus. To render the class of small engines so much more portable, so much more simple, and so much less costly as to remove the existing impediments to their use may certainly be accounted one of the most important problems of the present time, and I trust it is not presumptuous to hope that the cursory hints here given may accelerate the desired solution.

ON THE SHAPE AND SIZE OF THE EARTH.*

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Written for VAN NOSTRAND'S MAGAZINE.

II.—THE EARTH AS A SPHEROID.

As an oblate spheroid is a volume generated by the revolution of an ellipse about its minor axis, the equator and all the sections of the spheroid parallel to the equator are circles, and all sections made by planes passing through the axis of revolution are equal ellipses. Let a and b represent the lengths of the semi-major and semi-minor axes of this meridian ellipse, which are the same as the semi-equatorial and semi-polar diameters of the spheroid; when the values of a and b have been found all the other dimensions of the ellipse and the spheroid become known. At first we must understand the properties of the ellipse, then combining some of these with the data deduced by measurements we find, as was done in the last lecture for the circle, the form and size of the earth's meridian section.

The eccentricity and ellipticity of an ellipse are merely two fractions, the first defined by the equation

$$e=\frac{\sqrt{a^2-b^2}}{a}$$

and the second by

$$f=\frac{a-b}{a}$$

or in other words the eccentricity e is the distance between the foci divided by the major axis, and the ellipticity f is the amount of flattening at one of the poles divided by the semi-major axis. The relation between these two fractions is

$$f=1-\sqrt{1-e^2}$$

or

$$e=\sqrt{2f-f^2}.$$

From the definitions of e and f we may express b in terms of a as follows:

$$b=a\sqrt{1-e^2}$$

or

$$b=a(1-f).$$

The two quantities relating to the

* Three lectures originally prepared for the Civil Engineering Students of Lehigh University, as introductory to a course in Geodesy.

ellipse that we shall need most particularly to use are the length of the quadrant and of the radius of curvature at any point. These are deduced in mathematical discussions on the ellipse, with which you are familiar; we here simply note their values and consider them as proved. The length of the quadrant is

$$q=\frac{a\pi}{2}\left(1-\frac{e^2}{4}-\frac{3e^2}{64}-\dots\right)$$

or perhaps more conveniently

$$q=\frac{a\pi}{2}\left(1-\frac{f}{2}+\frac{f^2}{16}-\dots\right).$$

If l be the latitude of any point on the meridian ellipse, the radius of curvature of the curve at that point is

$$r=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l)^3}}.$$

For the equator, where $l=0°$, this has its least value $\frac{b^2}{a}$, but for the poles where $l=90°$ it has its greatest value $\frac{a^2}{b}$. Now in determining the form and size of the ellipse we may seek a and b or any two convenient functions of a and b. Those usually employed are a and e; when these have been found, b and q and f and r are also known from the above equations.

Were the earth a perfect sphere, one arc of a meridian measured with precision would be enough to deduce the value of its radius. As it is, however, plainly a spheroid, and as a spheroid requires two dimensions for establishing its size, it would seem that two measured arcs of meridians are at least required. Let m_1 and m_2 be the measured lengths of two meridian arcs, φ_1 and φ_2 their amplitudes, that is, the number of degrees of latitude between their northern and southern extremities, l_1 and l_2 their middle latitudes, r_1 and r_2 the radii of curvature of their middle points. Regarding these arcs as arcs of circles their radii of curvature, as shown in the last lecture, are

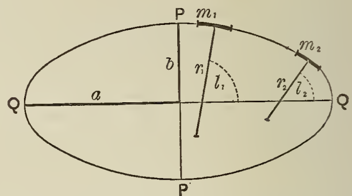
$$r_1=57.29578\frac{m_1}{\varphi_1}$$

$$r_2=57.29578\frac{m_2}{\varphi_2}.$$

Considering now the middle points of these arcs as lying upon the circumference of an ellipse whose semi-major axis is a and eccentricity e, these radii are

$$r_1=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_1)^3}}$$

$$r_2=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_2)^3}}$$



Equating these values gives the two following conditions:

$$57.29578\frac{m_1}{\varphi_1}=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_1)^3}}$$

$$57.29578\frac{m_2}{\varphi_2}=\frac{a(1-e^2)}{\sqrt{(1-e^2\sin^2 l_2)^3}}$$

which contain eight quantities all known except a and e. It is evident that a and e will be the more accurately determined the nearer to the pole one of the arcs be taken, and the nearer to the equator the other. To solve these equations observe that if the first be divided by the second, we obtain an equation containing e^2 alone, from which

$$e^2=\frac{1-\left(\frac{m_1\varphi_2}{m_2\varphi_1}\right)^{\frac{2}{3}}}{\sin^2 l_2-\left(\frac{m_1\varphi_2}{m_2\varphi_1}\right)^{\frac{2}{3}}\sin^2 l_1}.$$

Then to find a place the value of e in either of the above equations and solve for a.

For an example let us take the two arcs measured about the year 1737, by astronomers in the employ of the French Academy, one in Lapland and the other in Peru. The data are as follows:

Lapland Arc:
Length=92778 toises=180827.7 meters.
Lat. of N. end= +67° 8′ 49.″83
Lat. of S. end= +65 31 30.26

Peruvian Arc:
Length=176875.5 toises
=344735.9 meters.
Lat. of N. end= +0° 2′ 31.″39
Lat. of S. end= −3 4 32.07.

Calling the Lapland Arc No. 1 and the Peruvian No. 2, we find l_1 and l_2 by taking the mean of the two latitudes in each case, and φ_1 and φ_2 by taking their difference. Then

$$m_1 = 180827.7 \text{ meters}$$
$$\varphi_1 = 1.^\circ 622102$$
$$l_1 = +66^\circ\ 20'\ 10.''05$$
$$m_2 = 344735.9 \text{ meters}$$
$$\varphi_2 = 3.^\circ 117628$$
$$l_2 = -1^\circ\ 31'\ 0.''34.$$

Substituting these values in the above expression for e^2 we find

$$e^2 = 0.00643506$$

or $$e = 0.08022.$$

Inserting this value of e^2 in either of the original equations and solving for a we find

$$a = 6376568 \text{ meters.}$$

From the value of e^2 we find also

$$f = 0.0032228$$

and then $$b = 6356020 \text{ meters}$$
$$q = 10000150 \text{ meters.}$$

It is often customary to state the value of the ellipticity as a vulgar fraction whose numerator is unity, since thus a clearer idea is presented of the flattening at the poles. In this case the fraction is

$$f = \frac{1}{310.3}$$

that is, the amount of the flattening at one of the poles is about $\frac{1}{310}$th of the equatorial radius. In the same way the eccentricity may be written

$$e = \frac{1}{12.5}$$

or the distance of the focus of the ellipse from the center is about $\frac{1}{12.5}$th of the equatorial radius. These fractions are both somewhat too small for the actual spheroid, as will be shown in future paragraphs.

Let us now go back to the year 1745 or thereabouts, when, it will be remembered, the results of the surveys instituted by the French Academy became known. These results have been stated in the previous lecture, but it may be well to note them here again.

Arc.	Mean lat.	Length of 1° of latitude.
		Meters.
Lapland	+66°20′	111949
France	+49 22	111212
Peru	− 1 34	110565

By the method above explained, or by other similar methods, these data may be combined in three different ways to deduce the shape and size of the earth, assuming it to be a spheroid of revolution. These combinations gave for the ellipticity:

From Lapland and French Arcs, $\frac{1}{145}$
From Lapland and Peruvian Arcs, $\frac{1}{310}$
From French and Peruvian Arcs, $\frac{1}{304}$.

Now if the earth be a spheroid of revolution, and if the measurements be well and truly made, then these values of the ellipticity should be the same. As, however, they disagree, the conclusion is ea y to make that either the assumption of a spheroidal surface is incorrect or the surveys are inaccurate. To settle this question there were measured in the following fifty years a number of meridian arcs in different parts of the world, one in South Africa by Lacaille, one in Italy by Boscovich, one in America by Mason and Dixon, one in Hungary by Liesganig, and one in Lapland by Svanberg, while in France, England and India, geodetic surveys furnished also the materials for the deduction of other arcs. Most important of all was the investigation undertaken by the French for the derivation of the length of the meter, the surveys for which with the accompanying office-work lasted from 1792 to 1807. This work was under the charge of the celebrated astronomers Delambre and Méchain, and the meridian arc extended from the latitude of Dunkirk on the north to that of Barcelona on the south, embracing an amplitude of nearly ten degrees. In this survey the methods for the measurement of bases and angles were greatly improved, and in fact here approached for the first time to modern precision. The results, as finally published in 1810, were,

length of arc = 551584.7 toises
amplitude = 9° 40′ 23.″89

and these were combined with the corresponding values in the Peruvian arc to find the ellipticity. The combination gave

$$f = \frac{1}{334}$$

and then the length of the quadrant was found to be

$q=5130740$ toises.

Now it had been established by law that the meter should be one ten-millionth part of the quadrant. Hence

$$1 \text{ meter}=0.513074 \text{ toises}$$

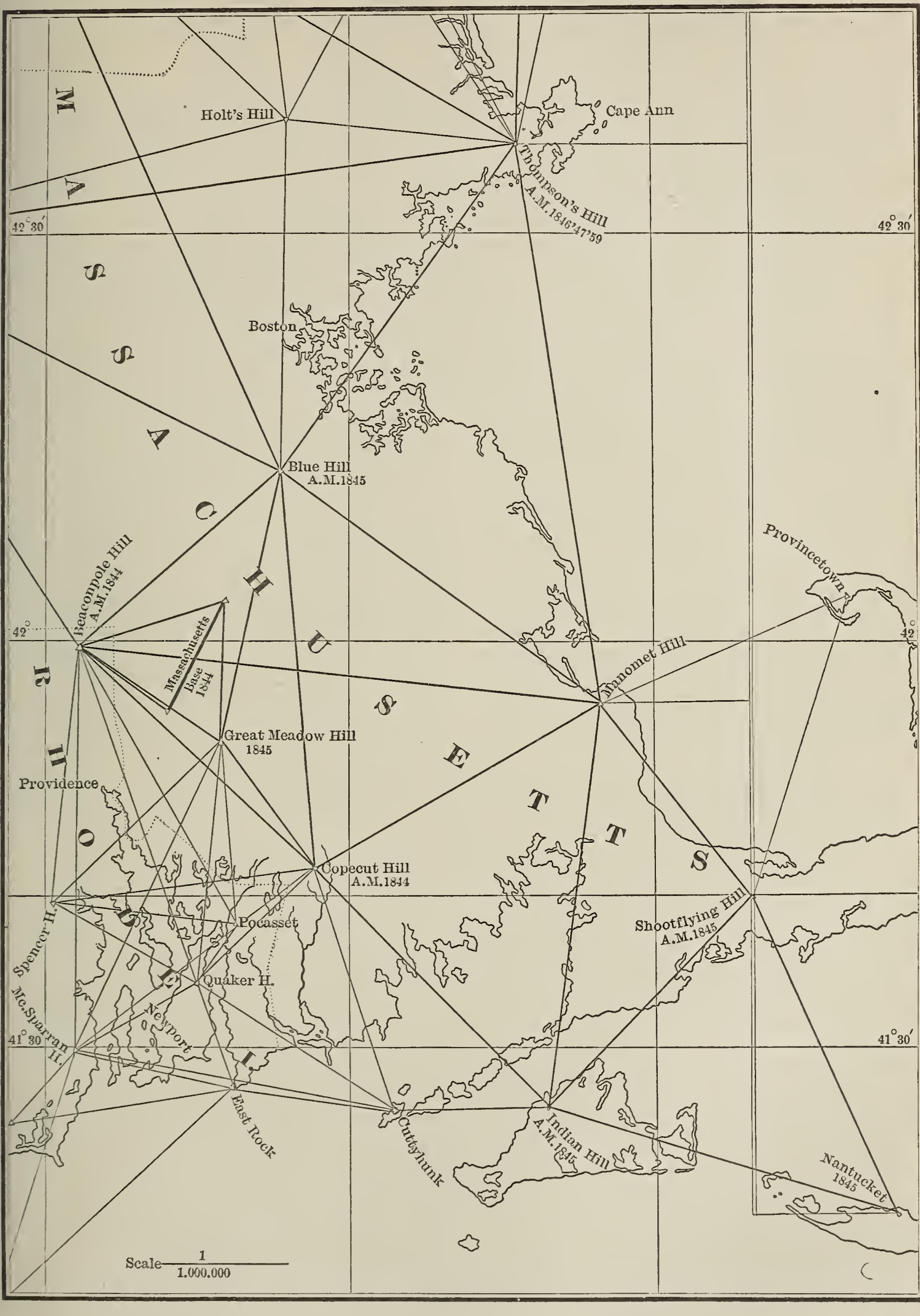
and of course $q=10\,000\,000$ meters.

During the present century the measurement of meridian arcs has generally been carried on only in connection with the triangulations which form the basis of extensive topographical surveys. Central Europe is now covered with a net of triangles, and the same is true of portions of Russia, India and the United States. To obtain a general idea of the processes involved in such work, let us consider for a few moments a portion of the triangulation executed by the United States Coast Survey in New England, and which has furnished a meridian arc of about 3° 22′ in amplitude, or about 233 miles in length. Sketch No. 3, in the Coast Survey Report for 1875, exhibits the plan of the triangulation.* Near the north-eastern corner of the State of Rhode Island you see a line called the Massachusetts base, which was measured along the track of the Boston and Providence railroad in 1844, with a base apparatus consisting of four bars placed in contact with each other in a wooden box, and provided with micrometer microscopes by which wires could be brought into optical contact with the ends of the bars and with eight thermometers to ascertain the temperature. The length of the base line is nearly 10½ miles, and its measurement occupied about three months, the exact result corrected for temperature, inclination, and elevation above mean ocean level being 17326.376 U. S. meters with a probable error of 0.036 meters. About 295 miles north-easterly is the Epping base, and 230 south-westerly is the Fire Island base, which have also been measured with the same careful attention. From the comparison of the measured lengths of these base lines with their lengths as computed through the triangulation, published in the Coast Survey Report for 1865, we extract the following values of the Massachusetts base:

Measured length......	17326.376	meters
Calculated from Epping base.............	17326.528	"
Calculated from Fire Island base.......	17326.445	"

which show the great accuracy of the work, since the differences of these results exhibit the accumulated errors of all the angle work between the bases as well as those of the linear measurements. The map also shows how from the base line the position of Beaconpole Hill is determined, then that of Great Meadow Hill, and how from these two the triangulation is extended to Blue Hill, and thence onward in all directions. To select these stations a careful reconnaissance was made, the proper tripods and signals were erected, and then there was placed over each station in succession a great theodolite with a circle thirty inches in diameter, graduated to five minutes and reading to single seconds by three micrometer microscopes, and with it skilled observers measured all the horizontal angles, each being taken many times on different parts of the arc and in different positions of the telescope, so as to eliminate the instrumental errors. At some of the stations too astronomical theodolites were placed to determine, by observations on circumpolar stars, the meridian, and thence the azimuths of the sides of the triangles, and to find the latitudes a portable zenith telescope was used to measure the difference of the zenith distances of many carefully selected pairs of stars. Longitudes of some of the points are found by comparing with the electric telegraph the local times with that of some established observatory. From these stations of the larger or primary triangles there are formed smaller or secondary triangles, from which the plane table surveys and other topographical work extend out all along the coast line. But before the hydrographic charts can be published, a great deal of computation is necessary. The observed angles must be adjusted by the method of least squares, so as to balance in the most advantageous way the small irregular errors of observation. From the bases the lengths of all the sides of the triangles are found, the spherical excesses computed, the adjustments made, and, finally, the latitudes and longitudes

* Fig. 6 is a copy of a small part of this sketch, and shows only the southern part of the meridian arc.



MASSACHUSETTS
RHODE IL.
Holt's Hill
Cape Ann
Thompson's Hill A.M.1846'47'59
Boston
Blue Hill A.M.1845
Beaconpole Hill A.M.1844
Massachusetts Base 1844
Great Meadow Hill 1845
Providence
Manomet Hill
Provincetown
Copecut Hill A.M.1844
Pocasset
Quaker H.
Spencer H.
Mc.Sparran H.
Newport
East Rock
Cuttyhunk
Indian Hill A.M.1845
Shootflying Hill A.M.1845
Nantucket 1845
42°30′
42°
41°30′
Scale 1/1.000.000

of each station determined. If now a chain of triangles runs approximately north and south for some distance, these calculations can be readily extended so as to deduce a meridian arc. In the map before us, you will notice two parallel lines drawn through the station Shootflying Hill. This is an arc of a meridian deduced from the New England primary triangulation, by methods explained in the Coast Survey Report for 1868. Its southern extremity is in the latitude of Nantucket, and its northern in that of Farmington, Maine. You can see in the map the broken lines drawn perpendicular to the meridian from the several stations; the portions intercepted between these perpendiculars are the meridian distances corresponding to the differences of latitude. The following are the numerical results:

Stations.	Observed Astr'nomical Latitudes.	Distances between parallels.
		meters.
Farmington.......	44°40′12.″06	58567.41
Sebattis...........	44 8 37. 60	42718.32
Mt. Independence..	43 45 34. 43	59535.58
Agamenticus.....	43 13 24. 98	67971.93
Thompson........	42 36 38. 28	76002.37
Manomet.........	41 55 35. 33	70429.77
Nantucket........	41 17 32. 86	

The total length of the arc is 375225.38 meters, with a probable error of 1.3 meters. The probable error of an observed astronomical latitude does not exceed 0.1 second. From the whole arc the length of one minute is found to be 1851.6 meters, with a probable error of 0.6 meters, and the length of one degree in the middle latitude of the arc is 111096 meters, with a probable error of 36 meters.

It is impossible to regard attentively these accurate measures, without a feeling of wonder at the remarkable growth of geodetic science during the present century, not only in instrumental precision, but in theoretical methods of computation. A hundred years ago, for instance, the measurement of the angles of geodetic triangles was so rude that the spherical excess remained undetected, and the processes of adjustment by the method of least squares were entirely unknown. The zenith telescope for latitude observations, the electric telegraph for longitude determination, the self compensating base apparatus, the method of repetitions in angle measurement, the comparison of the precision of observations by their probable errors, and their adjustment by minimum squares, the theory of speroidal geodesy, all these and many other improvements have been introduced, and pefected in the present century, almost within the memory of men now living.

We have explained above a method by which the size of the earth regarded as an oblate spheroid, may be found by the combination of two measured parts of meridian arcs, and we have also said that at the year 1760, or thereabouts, such combinations of several arcs, taken two by two, gave discordant values for the ellipticity and the length of the quadrant, and that hence it became evident, that either the earth's meridian section was not an ellipse, or that the measurements were not accurately made. Towards the end of the last century, many attempts were made at rational combinations of the accumulating data, the most important, perhaps, being one by Boscovich in 1760, and two by Laplace published in 1793 and 1799 respectively. In order to obtain a clear idea of the problem, let us state the very data used by Laplace in

No.	Locality of arc.	Middle latitude.	Length of one degree.
			toises.
1	Lapland.......	66° 20′	57405
2	Holland.......	52 4	57145
3	France........	49 23	57074½
4	Austria........	48 43	57086
5	France........	45 43	57034
6	Italy..........	43 1	56979
7	Pennsylvania..	39 12	56888
8	Peru..........	0 0	56753
9	CapeGood Hope	33 18	57037

his first discussion. The numbers in the last column are found by dividing the linear length of each arc in toises by its amplitude in degrees. Now if we consider short lengths as arcs of a circle, they are directly proportional to the lengths of the radii at their middle points, and if we take these middle points as situated on an ellipse, having the earth's equatorial and polar diameters for its axes, the lengths of the degrees are directly proportional to the corresponding radii of curvature of the ellipse. Thus if d be the length of any degree, D the length of one at the equator, and r and R the corresponding radii of curvature, we have

$$\frac{D}{d}=\frac{R}{r}$$

Inserting here for r, its value at latitude l, and R its value at the latitude 0°, as given in the early part of this lecture, we find

$$d=D\,(1-e^2\sin^2 l)^{-\frac{3}{2}}$$

which, after development by the binomial formula, may be written

$$d=D(1+\tfrac{3}{2}e^2\sin^2 l+\tfrac{15}{8}e^4\sin^4 l+\ \ldots\ )$$

Now D, the length of one degree at the equator, may be expressed in terms of the ecentricity e, and the semi-equatorial diameter, a. Thus

$$D=R\frac{\pi}{180}=\frac{b^2}{a}.\frac{\pi}{180}=\frac{\pi a}{180}(1-e^2)$$

and inserting this, we find for d

$$d=\frac{\pi a}{180}(1-e^2)\,(1+\tfrac{3}{2}e^2\sin^2 l+\tfrac{15}{8}e^4\sin^4 l+\ldots).$$

It thus appears that the length of a degree can be expressed by an equation of the form

$$d=M+N\sin^2 l+P\sin^4 l+\ldots\ldots$$

in which

$$M=\frac{\pi a(1-e^2)}{180}$$

$$N=\frac{3\pi ae^2(1-e^2)}{360}$$

$$P=\frac{15\pi ae^4(1-e^2)}{14400}$$

$$\ldots=\ldots\ldots$$

and Laplace, in discussing the above data, considered that it was unnecessary to include powers of e higher than the square, and hence that

$$d=M+N\sin^2 l,$$

expressed the length of one degree of the meridian ellipse. Now the problem is this: to deduce from the above seven meridian arcs the values of M and N, so as to obtain an expression for d, the length of one degree of latitude at the latitude l, and then from these values of M and N to find a and e, and all the other elements of the spheroid. And the first step must be to insert in the formula, the values of d and l for each of the arcs. Thus for arc No. 1,

$$d=57405 \text{ toises}$$
$$l=66°\ 20'$$
$$\sin l=0.93565$$
$$\sin l^2=0.83887$$

and $57405=M+0.83887N$

In this manner we form the nine following equations:

$$\begin{aligned}
57405\ &=M+0.83887N\\
57145\ &=M+0.62209N\\
57074\tfrac{1}{2}&=M+0.57621N\\
57086\ &=M+0.56469N\\
57034\ &=M+0.51251N\\
56979\ &=M+0.46541N\\
56888\ &=M+0.39946N\\
56753\ &=M+0.00000N\\
57037\ &=M+0.30143N
\end{aligned}$$

and from them the values of M and N are to be determined. Now two equations are sufficient to find two unknown quantities, and hence it seems that no values of M and N can be given that will exactly satisfy all of the nine equations. The best that can be done is to find such values as will satisfy them in the most reasonable manner, or with the least discrepancies. To make this idea more definite suppose that the second members of these equations be transposed to the first, giving equations of the form

$$d—M—N\sin^2 l=0,$$

then since M and N can not exactly reduce them to zero, we may write

$$\begin{aligned}
57405\ &-M-0.83887N=x_1\\
57145\ &-M-0.62209N=x_2\\
57074\tfrac{1}{2}&-M-0.57621N=x_3\\
&\text{etc,}\qquad \text{etc,}\qquad \text{etc,}
\end{aligned}$$

in which x_1, x_2, x_3, etc., are small errors or residuals. Now Laplace, following the idea of Boscovich, conceived that the most reasonable values of M and N were those which would render the algebraic sum of the errors, x_1, x_2, x_3, etc., equal to zero, and also make the sum of the same errors, all taken with the plus sign, a minimum. By introducing these two conditions, he was able to reduce the nine equations to two, from which he found

$$M=56753 \text{ toises},$$
$$N=613.1 \text{ toises},$$

His value of the length d in toises of one degree at the latitude l, was hence

$$d=56753+613.1\sin^2 l$$

From the values of M and N, it was now easy to find the ellipticity f. Thus, from the above definitions of M and N, we have

$$\frac{N}{M}=\frac{3}{2}e^2$$

from which

$$e^2=\frac{2\times 613.1}{3\times 56753}=0.007202$$

and then $f=0.0036=\frac{1}{278}$.

From the expression for either M or N it is also easy to find a the semi-major axis, whence b the semi-minor axis, and q the quadrant of the ellipse become known. The last step in Laplace's investigation is the comparison of the observed values of the lengths of some of the degrees with those found from his formula for d. For the Lapland arc, for instance, observation gives

$$d=57405 \text{ toises,}$$

while computation gives

$$d=56753+613.1\sin^2 66°20'=57267.3$$

the difference, or error, being

137.7 toises,

a distance equal to about 268 meters, or nearly 9 seconds of latitude. These errors, says Laplace, are too great to be admitted, and it must be concluded that the earth deviates materially from an elliptical figure.

At the beginning of the present century it was the prevailing opinion among scientists, founded on investigations similar to that of Laplace, that the contradictions in the data derived from meridian arcs, when combined on the hypothesis of an oblate spheroidal surface, could not be attributed to the inaccuracies of surveys, but must be due in part, at least, to deviations of the earth's figure from the assumed form. This conclusion, although founded on data furnished by surveys that would now-a-days be considered rude, has been confirmed by all later investigations, so that it can be laid down as a demonstrated fact that this earth is not an oblate spheroid. And yet it must never be forgotten that the actual deviations from that form are very small when compared with the great size of the globe itself. In fully half the practical problems into which the shape of the earth enters, it is sufficient to consider it a sphere; in others its variation from a spherical form must be noced, and there we regard it as spheroidal; cases where it would be requisite to regard its deviation from the spheroidal form will rarely if ever occur in any engineering question, yet for the sake of science we feel curious to determine the laws governing it, and these perhaps may at some future time be determined. Now, in the early part of the present century it was agreed by all, notwithstanding the discrepancies of measurements, that for the practical purposes of mathematical geography and geodesy it was highly desirable to determine the elements of an ellipse agreeing as closely as possible with the actual meridian section of the earth. Hence various methods of combination were tried, and as new data accumulated they were quickly added to the store already on hand, crowding out gradually, to be sure, the older data of less accurate surveys. The most important one of these methods of combination, which is the one now exclusively used for the discussion of precise measurements, was the method of least squares—and a few words must be said concerning its history and explanatory of its processes.

In the year 1805 Legendre announced a process for the adjustment of observations founded upon the principle that the sum of the squares of the residual errors should be made a minimum, and which he named "method of least squares." He gave no proof of the advantage of the principle, but stated it merely as one which seemed to him to be the simplest and the most general and to secure the most plausible balancing of errors of observation. He deduced some practical rules for its use and applied it to a numerical example which, it is interesting to observe, was a discussion of the earth's elliptic meridian as resulting from five portions of the long French arc. But in 1809 Gauss published a theoretical investigation in which he showed from the theory of probability that this method gave the most probable results of the quantities sought to be determined, provided that the observations were subject only to accidental errors—that is, to errors governed by no laws but those of chance. This proof caused the method to be immediately accepted by mathematicians as the only rational process for the adjustment of measurements, and in the following quarter of a century it was fully developed by the labors of Gauss, Bessel and others. And here it should not be forgotten that in our own country and in the year 1808, one year in advance of Gauss, Adrian published a proof of the same principle, which unfortunately remained unknown to mathematicians for more than sixty years. To Bessel is due the first idea of the comparison of the accuracy of observations by their probable errors and also many valuable applications of the method to geodetic measurements. It has been truly said that the method of least squares is "the most valuable arithmetical process that has been invoked to aid the progress of the exact sciences;" for the values deduced by it are those which have the greatest probability. With the aid of the theory of probable error the precision of the observations is readily inferred, and uniformity is secured in processes of adjustment and comparison. To explain the operation of the method, or rather one of its most commonly used operations let us take a numerical example, and let it be a problem relating to the determination of the earth's ellipticity by pendulum experiments. The following are the data—thirteen values of the length of a second's pendulum in various parts of the earth as observed by Sabine in the years 1822–24:

Place.	Latitude.	Length of seconds pendulum.
		English inches.
Spitzbergen.	+79°49′58″	39.21469
Greenland ..	74 32 19	39.20335
Hammerfest.	70 40 5	39.19519
Drontheim..	63 25 54	39.17456
London.....	51 31 8	39.13929
New York..	40 42 43	39.10168
Jamaica	17 56 7	39.03510
Trinidad....	10 38 56	39.01884
Sierra Leone.	8 29 28	39.01997
St. Thomas..	0 24 41	39.02074
Maranham ..	—2 31 43	39.01214
Ascension...	7 55 48	39.02410
Bahia.......	12 59 21	39.02425

The ellipticity of the earth may be derived from these observations by means of a remarkable theorem published by Clairaut in 1743, namely

$$\frac{g}{G}=1+(\tfrac{5}{2}k-f)\sin^2 l,$$

in which G is the force of gravity at the equator, g that at the latitude l, k the ratio of the centrifugal force at the equator to gravity, and f the ellipticity of the earth regarded as an oblate spheroid. This theorem is limited only by the conditions that the form of the earth is a spheroid of equilibrium assumed in the rotation on its axis, and that its material is homogeneous in each spheroidal stratum. Now, the length of a pendulum beating seconds is proportional to the force of gravity, hence if S represent the length of such a pendulum at the equator and s the length at the latitude l, the theorem may be also written

$$\frac{s}{S}=1+(\tfrac{5}{2}k-f)\sin^2 l.$$

We see then that

$$s=S+T\sin^2 l$$

in which

$$T=S(\tfrac{5}{2}k-f)$$

is a general expression for the length of a second's pendulum. When T and S have been found, their ratio gives the value of $\frac{5}{2}k-f$. and then f the ellipticity becomes known, since k is easily determined with an error of less than half a unit in its third significant figure; (see your elementary text-book on mechanics or astronomy for a proof that $k=\frac{1}{289}$). For each one of the above observations we next write an observation equation, by substituting for s and l their values in the formula

$$s=S+T\sin^2 l.$$

Thus, for the first

$$s=39.21469$$
$$l=79°\ 49'\ 58''$$
$$\sin l=0.9842665$$
$$\sin^2 l=0.9688402$$
$$39.21469=S+0.9688402T$$

In this manner we find the following thirteen observation equations:

$$39.21469=S+0.9688402T$$
$$39.20335=S+0.9289304T$$
$$39.19519=S+0.8904120T$$
$$39.17456=S+0.7999544T$$
$$39.13929=S+0.6127966T$$
$$39.10168=S+0.4254385T$$
$$39.03510=S+0.0948286T$$
$$39.01884=S+0.0341473T$$
$$39.01997=S+0.0218023T$$
$$39.02074=S+0.0000515T$$
$$39.01214=S+0.0019464T$$
$$39.02410=S+0.0190338T$$
$$39.02425=S+0.0505201T$$

Now, since the left hand members of these equations are affected by errors of observations it will not be possible to find values for S and T that will exactly satisfy all the equations; the best that we can do is to find their most probable values, and this is done by the following rule, which you will find proved in all books on the method of least squares: Deduce a normal equation for S by multiplying each observation equation by the coefficient of S in that equation, and adding the results; deduce also a normal equation for T by multiplying each observation equation by the coefficient of T in that equation and adding the results; thus we shall have two normal equations each containing two unknown quantities, and the solution of these equations will give us the most probable values of S and T. In this case the coefficient of S in each of the equations is unity, multiplying each equation by unity leaves it unchanged, and we have simply to take their sum to get the first normal equation,

$$508.1839D = 13S + 4.8487021T.$$

To find the second normal equation we multiply the first observation equation by 0.9688402, the second by 0.9289304, and so on, and by addition of these results we have

$$189.944469 = 4.8487021S + 3.7043941T.$$

The solution of these two normal equations gives

S = 39.01568 English inches
T = 0.20213 " "

as the most probable values that can be deduced from the thirteen observations. Hence the length of the seconds pendulum at any latitude l may be written

$$s = 39.01568 + 0.20213 \sin^2 l.$$

Lastly, we find the ellipticity of the earth by the formula

$$f = \tfrac{5}{2}k - \frac{T}{S}$$

whence $f = 0.0086505 - 0.0051807$

or $f = \dfrac{1}{288.2}$

Before leaving the subject of the pendulum, which we have been obliged to treat very briefly, we will mention that numerous observations of this kind have been made in various parts of the earth, and that the value of the ellipticity deduced from them is $\dfrac{1}{288.9}$.

During the present century there have been published many investigations and combinations by the method of least squares of the data furnished by the measurement of meridian arcs. The principal results of the most important of these made on the hypothesis of a spheroidal figure are given in the following table:

Year.	By whom.	Ellipticity.	Quadrant in meters.
1819	Walbeck	1:302.8	10 000 268
1830	Schmidt	1:297.5	10 000 075
1830	Airy	1:299.3	10 000 976
1841	Bessel	1:299.2	10 000 856
1856	Clarke	1:298.1	10 001 515
1863	Pratt	1.295.3	10 001 924
1866	Clarke	1:295	10 001 887
1868	Fischer	1:288.5	10 001 714
1872	Listing	1:289	10 000 218
1878	Jordan	1:286.5	10 000 681
1878	Clarke	1:293.5	10 001 872

Let us now endeavor to state briefly how such calculations are made. The principle of the method of least squares, it will be remembered, requires that the sum of the squares of the errors of observation shall be rendered a minimum. The first inquiry then is, where are the errors of observation in a meridian arc, are they in the linear distance or in the angular amplitude? As long ago as a hundred years, it was suspected that the discrepancies in such surveys were due to deflections of the plumb lines from a vertical, caused by the attraction of mountains, whereby observers were deceived in the position of the zenith and the true level of a station, and hence deduced false values of its latitude. It needs indeed not an extensive knowledge of the modern accurate methods of geodesy to become convinced that the errors in the linear distances are very small; on the U. S. Coast Survey, for instance, the probable error in the computed length of any side of the primary triangulation is its $\frac{1}{288000}$th part, which amounts to less than a quarter of an inch in a mile, or two feet in a hundred miles. The probable error of observation in the latitude of a station is also small, yet it is easy to see that it may be affected with a constant error, due to the deviation of the vertical from the normal to the spheroid. To illustrate, let the annexed sketch represent a portion of a meridian section of the earth. O is the ocean, M a mountain and A a latitude station between them; *sss* is a part of the meridian ellipse coinciding with the ocean surface; AC represents the normal to the ellipse, and AH, perpendicular to AC, the true level for the station A. Now owing to the attraction of the mountain M, the plumb line is drawn southward from the normal to the position A*c*, and the apparent level is depressed to A*h*. If AP be parallel to the earth's axis, and hence pointing toward

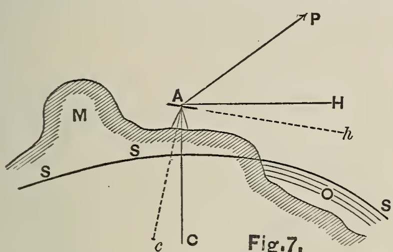


Fig.7.

the pole, the angle PAH is the latitude of A for the spheroid *sss*; but as the instrument at A can only be set for the level A*h* the observed latitude is PA*h*, which is greater than the true by the angle HA*h*. These differences or errors are usually not large—rarely exceeding ten seconds—yet, since a single second of latitude corresponds to about 31 meters or 101 feet, it is evident that the error in the linear distance of a meridian arc is very small, in comparison with that due to a few seconds of error in the difference of latitude. In treating such measurements by the method of least squares we hence regard the distances as without error, and state observation equations which are to be solved by making the sum of the squares of the errors in the latitudes a minimum. Such equations may be stated by writing an expression for an arc of an ellipse in terms of the observed latitudes l_1 and l_2, and measured length of a meridian arc, then in this placing l_1+x_1 and l_2+x_2, instead of l_1 and l_2, the letters x_1 and x_2 denoting the errors in latitude at the stations 1 and 2. The expression will take the form

$$x_2 - x_1 = m + n\text{S} + p\text{T}$$

in which m, n and p are known functions of the observed quantities, and S and T are known functions of the elements of the ellipse whose values are sought. If there are several latitude stations in a single arc, as is generally the case, one of them should be taken as a reference station, and each error written in terms of the error there. Thus if there be four latitude stations, we write

$$\begin{aligned} x_1 &= x_1 \\ x_2 &= x_1 + m + n\text{S} + p\text{T} \\ x_3 &= x_1 + m' + n'\text{S} + p'\text{T} \\ x_4 &= x_1 + m'' + n''\text{S} + p''\text{T} \end{aligned}$$

In like manner there will be a similar series for each arc, each series containing as many equations as there are latitude stations. The first members of these are the latitude errors in regular order, and the sum of the squares of these are to be made a minimum to find the most probable values of S and T; this is done by deriving normal equations for the left hand members by the usual rule. These normal equations will contain as unknown quantites S and T and as many errors, x_1, x_5, etc., as there are meridian arcs. When these equations have been solved it is easy to deduce from S and T the values of the elements of the ellipse. Such in brief is the method; but to explain all the details of calculation with the devices for saving labor, and ensuring accuracy is not possible here—it would indeed be matter enough for more than a whole lecture.

The most important, perhaps, of these discussions is that of Bessel, published in 1837, and revised in 1841 because in the meantime an error had been detected in the French survey. We call it the most important, not merely on account of the careful scrutiny given to all the data and the precise processes of computation employed, but also because its results have been since widely adopted and used in scientific works and geodetic literature. The material employed by Bessel consisted of ten meridian arcs—one in Lapland, one each in Russia, Prussia, Denmark, Hanover, England and France, two in India, and lastly, the one in Peru. The sum of the amplitudes of these arcs is about 50.5°, and they include 38 latitude stations. In the manner briefly described above there were written 38 observation equations, from which 12 normal equations containing 12 unknown quantities, were deduced. The solution of these gave the elements of the meridian ellipse, and also the relative errors in the latitudes due to the deflections of the plumb lines. The greatest of these errors was 6.″45, and the mean value 2.″64. The spheroid resulting from this investigation is often called Bessel's spheroid, and the elements of the generating ellipse Bessel's elements; the values of these will be given below.

In 1866 Clarke of the British Ordnance Survey, published a valuable discussion, which included a minute comparison of all the standards of measure that had been used in the various countries. The data were derived from six arcs, situated in Russia, Great Britain, France, India, Peru and South Africa, including 40 latitude stations, and in total embracing an amplitude of over 76°. This investigation is generally regarded as the most important one of the last quarter of a century, and the values derived by it as more precise than those of Bessel. The Clarke spheroid, as it is often called, has been adopted in some of the geodetic calculations of the United States Coast Survey Office, and the constants and tables computed from Bessel's elements are now being changed to correspond with those of Clarke. It is hence necessary for the student of geodesy to be acquainted with the differences between the two spheroids, and in the following table the complete elements of the meridian ellipses of both are given:

	Bessel's Elements. 1841.	Clarke's Elements. 1866.
Semi-major axis a in meters	6 377 397	6 378 206
" " " English Feet	20 923 597	20 926 062
Semi-minor axis b in Meters	6 356 079	6 356 584
" " " English Feet	20 853 654	20 855 121
Meridian Quadrant in Meters	10 000 856	10 001 887
Eccentricity e	0.081 696	0.082 271
" e^2	0.006 674	0.006 768
Ellipticity f	$\frac{1}{299}$	$\frac{1}{295}$

From these it is easy to compute the radius of curvature of the ellipses for any latitude, and then to find the lengths of the degrees of latitude and longitude, which are required in the construction of map projections. We give a few of these values in order to exhibit more clearly the differences between the two spheroids:

Lat.	1 degree of latitude on the spheroid of	
	Bessel.	Clarke.
	Meters.	Meters.
90°	111 680	111 699
50°	111 216	111 229
45	119	131
40	023	033
35	929	937
30	841	848
25	762	768
0	110 564	110 567

For the lengths of the degrees of longitude, there is likewise a difference of about twelve meters in the results deduced from the elements of the two spheroids. For instance, at 50° and at 40° on the Bessel spheroid we have 71687 and 85384 meters as the lengths of one degree of the parallel, while the corresponding values for the Clarke spheroid are 71698 and 85396 meters, On a scale of $\frac{1}{10000}$, twelve meters would be 1.2 millimeters; but a sheet of paper exhibiting a whole degree must be several meters in width and length, and hence it would seem that for the practical purposes of map projection the differences between the two spheroids are too small to be generally regarded. The length in English feet of one degree of latitude at any latitude l on the Clarke spheroid is given by the expression

$$d=364609.87-1857.14\cos 2l+3.94\cos 4l$$

and the lengths of the degrees of longi tude may be computed from the formula

$$365538.48\cos l-310.17\cos 3l+0.39\cos 5l$$

and after dividing the constants by the number 3.28086933, they give the lengths in meters.

The form of the earth may also be deduced from measured arcs of parallels between points whose longitude are known, but as yet geodetic surveys have not furnished sufficient material to effect a satisfactory discussion. It is evident that such arcs will have a particular value in determining whether or not the equator and the parallels are really circles. Regarding the form as spheroidal the elements may likewise be found from the length of a geodetic line whose end latitudes and azimuths have been observed. Such a line extending through the Atlantic States from Maine to Georgia, has been deduced trom the primary triangulation of the United States Coast Survey, but its data and the results found therefrom have not yet been published. We learn, however, (from the Proceedings of the European International Geodetic Association) that its influence upon our knowledge of the figure of the earth is to but slightly increase the dimensions of Clarke's spheroid, without appreciably changing his value of the ellipticity.

By regarding the figure of the earth as one of equilibrium assumed under the action of forces due to its gravity and rotation when in a homogeneous fluid state, the value of the ellipticity may be computed from purely theoretical considerations. Newton deduced in this way the value $f=\frac{1}{230}$, and an investigation by Laplace proves that the ellipticity of a homogeneous fluid spheroid revolving about an axis, and whose form does not differ materially from that of a sphere, is equal to five-fourths of the ratio of the centrifugal force at the equator to the gravitative force. As this ratio is known to be $\frac{1}{289}$, the theorem gives $\frac{1}{231}$ for the ellipticity. But as this value is much too great the conclusion must be that the earth is not homogeneous.

Lastly, the shape of the earth may be found from astronomical observations and calculations. Irregularities in the motion of the moon were at first explained by the deviation of the earth from a spherical form, and then by precise measurement of the extent of the irregularities; the ellipticity was computed, the value determined by Airy being $\frac{1}{297}$. As the precession of the equinoxes is due to the attraction of the sun and moon on the excess of matter around the earth's equator, it would seem as if the figure of the globe might be found from that phenomenon also.

Looking back now over the historical facts, as here so briefly presented, we may observe that the values of the ellipticity f and of the length of the quadrant q, as deduced from geodetic surveys, have both exhibited a tendency to increase as the data derived from such surveys have become more precise and numerous. About the year 1805 their values, as adopted in the celebrated work for the establishment of the meter, were

$$f=\frac{1}{334} \quad q=10\ 000\ 000 \text{ meters.}$$

In 1841 the investigation of Bessel gave

$$f=\frac{1}{299} \quad q=10\ 000\ 856 \text{ meters,}$$

and in 1866 Clarke found

$$f=\frac{1}{295} \quad q=10\ 001\ 887 \text{ meters.}$$

In addition to this we should bear in mind that the combination of numerous pendulum observations give, with considerable certainty,

$$f=\frac{1}{289},$$

and this value, it seems not improbable to suppose, may perhaps be ultimately deduced from geodetic measures when they become more widely extended over the surface of the earth. For very many problems it will be found convenient to keep in mind the following round numbers:

$$\text{Ellipticity}=\frac{1}{17^2}$$

$$\text{Eccentricity}=\frac{1}{12}$$

$$\text{Quadrant}=10001 \text{ kilometers.}$$

The following mnemonic rule may perhaps be of some use in remembering the values of the semi-equatorial and semi-polar diameters a and b: keep in mind the number 6400 kilometers (which is a perfect square), then a is 22 kilometers and b is 44 kilometers less than this. In the form of an equation

$$a=(6400-22) \text{ kilometers,}$$
$$b=(6400-44) \text{ kilometers;}$$

and the difference $a-b$ equals 22 kilometers. To convert these distances into miles is easy enough if the number of miles in a kilometer is known, but if there be any difficulty in remembering this let it be held fast from the mnemonic analogy that 5280 feet make one mile, but that 3280 feet make one kilometer.

Three hundred and fifty years ago when men began first to think about the shape of the earth, on which it was their privilege to live, they called it a sphere, and they made rude little measurements on its great surface to ascertain its size. These measurements, as we know, at length after nearly two centuries, reached an extent and precision sufficient to prove that its surface was not spherical. Then the earth was assumed to be a spheroid of revolution, and with the lapse of time the discrepancies in the data, when compared on that hypothesis, seemed to also indicate that the assumption was incorrect. Granting that the earth is a sphere, there has been found the radius of one representing it more closely than any other sphere; granting that it is a spheroid there has been also found, from the best existing data combined in the best manner, the dimensions of one that represent it more closely than any other spheroid. But as further and more accurate data accumulate alterations in these elements are sure to follow. In our last lecture we saw that the radius of the mean sphere could only be found by first knowing the elliptical dimensions, and here it might, perhaps, be also thought that the best determination of the most probable spheroid would be facilitated by some knowledge of the theory of the size and shape of the earth considered under forms and laws more complex than those thus far discussed. In our next lecture, then, let us endeavor to give some account of the present state of scientific knowledge and opinion concerning the earth as an ellipsoid with three unequal axes, the earth as an ovaloid, and lastly, the earth as a geoid.

SANITARY ENGINEERING

By Captain DOUGLAS GALTON, F. R. S..

Read at the Sanitary Science Congress, at Croydon.

From "The Builder."

The President of the Congress, Dr. Richardson, has explained to you in his lucid address that the life of a man on this globe might reasonably be expected to extend far beyond that to which he now ordinarily attains, provided he were removed from all the conditions unfavorable to long life which encompass him. Of these conditions some are hereditary, some arise from habits, and are personal to the individual. But there is another large class of conditions which are the direct result of the circumstances to which man is exposed in consequence of living in communities. All living beings are in a continual condition of change, which results in their throwing off from the body matters which poison earth, air, and water unless space, time, and opportunity are afforded for the counteraction of these deleterious effects. Epidemic diseases are observed to occur in very different degrees of intensity at different periods, amongst groups of population exposed to certain unhealthy conditions. Sometimes they take the form of pestilences, and immediately afterwards, the conditions remaining the same, they subside and all but disappear, again to renew their ravages at some future period. A careful examination of their phenomena has led to the discovery that whilst we have no knowledge of the causes which made these epidemics break out at one time and not at another, there are certain well-defined conditions which influence most materially not only their actual intensity, but also their frequency. Thus, intermittent fever was observed to disappear from places which it formerly ravaged after drainage of the soil and improved cultivation. It was next discovered that by cleanliness, fresh air, and diminised crowding the worst forms of pestilential fever, which used to commit ravages similar to those of the plague, disappeared entirely from English jails. The breathing of foul air contaminated by the breath of other persons appears to be the special agent which predisposes people to consumption and diseases of that class. Zymotic diseases,—namely, fevers. diarrhœa, cholera, dysentery, &c., —are most intensively active where there is overcrowding, and the repeated breathing of air already breathed, such air being further contaminated by moisture and exhalations from the skin. It is to the phisiologist and the chemist that we must look for the causes from which these baneful effects arise, and what are the conditions which should be altered to prevent or remove them. The engineer steps in after these causes have been pointed out, and it is for him to design the methods of prevention or removal. Five hundred years ago the population of the whole kingdom was only equal to the present population of the metropolis. When the first recorded census was taken in 1801, the population of England and Wales was less than 9,000,000.; it has now reached nearly 25,000,000. We are crowded together as we were never crowded before; our pursuits are more sedentary, our habits more luxurious. Houses increase in number, land is more valuable, the green fields more remote; our children are reared among bricks and paving-stones. It is daily becoming more and more impossible in the question of health for any one member of a community to separate his interest from that of his neighbors. If he places his house away from others, the air which he breathes may receive contamination from the neighboring district; the dirty water which he throws away may pollute the stream from which his neighbors draw their supply; and when a population congregates into towns the influence of the proceedings of each individual on his neighbor becomes strongly apparent. On these and similar grounds it is the interest of every person in a community that every other member of the community should live under conditions favorable to health. Each year, as the population increases and as dwellings multiply, so does the importance of promoting these conditions increase; and so long as preventible diseases exist throughout the country we must not delude ourselves with the idea that we have done more than touch the borders of sanitary improvement. Books inumerable have been written upon the question. Physiologists have invented every conceivable theory; patentees have invented every conceivable description of apparatus; engineers, architects, and builders, overwhelm you with professions of their knowledge of sanitary principles, and millions of money have been spent in furthering the schemes they have devised; and yet, in spite of all these efforts, there are few houses and very few towns where you would not easily detect some grievous sanitary blunders. I believe this to be due, in the first place, to the fact that the majority of men prefer anything to thinking for themselves. They like to obtain their knowledge as they do their hats—from a shop, ready made. In the second place, the sanitary education of the country has not been brought into a system. People seem to have thought that sanitary knowledge could be picked up anyhow. Yet the problems which the sanitary engineer and architect are called on to solve require for their solution a knowledge of the higher branches of physics, chemistry, geology, meteorology, and kindred sciences, and entail as close habits of observation as any other branch of the engineering profession. In the third place, it has always seemed to me that the system under which the Government advances money for sanitary works, whilst of great *primâ facie* advantage in one point of view, yet has its disadvantageous aspect. But it may be asked, what is sanitary knowledge? It is frequently assumed that drainage and water supply are the principal subjects which are embraced in the term; but these only make up a small part of the subject. At the present time there does not exist any treatise which brings to a focus the various problems of mechanical and physical science, upon which sanitary knowledge is based. The variety of these problems will be best illustrated by a few instances. A sanitarian tells us that health depends on pure air and pure water. If a site is to be selected, it requires a consideration of its position with respect to its surroundings. It requires a knowledge of the temperature of the air and of the soil; what are the prevailing winds; what is the amount and incidence of the rainfall; and what is the percolative capacity of the soil. The engineer cannot interfere with the general conditions of a climate, but he may produce important changes in the immediate surroundings of a locality; he may modify the condition and temperature of the soil; he may control atmospheric damp; he may arrange for the rapid removal of rainfall, or he may cause the rainfall to be retained in the soil, to be given out gradually in springs, instead of passing away in torrents to flood the neighboring districts. In the Island of Ascension, the power of retention of water in the soil exercised by the planting of trees was exemplified. That island formed a convenient point for ships to call at for obtaining water on their way home from the East Indies. It was a barren rock, to which formerly the water had to be conveyed in ships. About fifty years ago trees were planted on the island. These have thriven, and now the rain which falls, instead of passing away at once into the atmosphere by evaporation, is retained in a sufficient quantity to enable the water to be collected for the supply of the ships which call at the island. The engineer may modify the incidence of disease. Algeria, perhaps, offers some of the best illustrations of the manner in which engineering operations have remedied the evils of the proximity of marshes. Bona stands on a hill overlooking the sea; a plain of a deep rich vegetable soil extends southward from it, but little raised above the sea level. The plain receives not only the rainfall which falls on its surface, but the water from adjacent mountains, and is consequently saturated with wet. The population living on or near this plain suffered intensely from fever; entire regiments were destroyed by death and disease. It was at last determined to drain the plain. The result of this work was an immediate reduction of the sick and death rate. Fondouc, in Algeria, is situated on sloping ground, immediately above the marshy plain of the mitidja; mountain ranges rise immediately behind it. It was first occupied in 1844, and in the succeeding year half the population was swept away by fevers and dysentery. During the first twenty years the mortality was 10 per cent. The surrounding marsh has since been drained and cultivated, and the mortality now is 20 per 1,000. Similar instances may be quoted from our own possessions in India. In the northern Doab districts in the northwest provinces of India the excessive fever mortality for which these districts were noted has been mitigated by extensive drainage works, by means of which the water which formerly stagnated in the land is now led away by continuously flowing streams.

When a site has been selected, it is necessary to consider the question of the subsoil. The air does not cease where the ground begins, but air permeates the ground and occupies every space not filled by solid matter or by water. Thus it is the same thing to build on a dry gravelly soil where the interstices between the stones are naturally somewhat large, as to build over a stratum of air. The air moves in and out of the soil in proportion to barometric pressure, and with reference to the wind. If there is much water in the soil, the air carries with it watery vapors, and is cold, and such a site is called damp. A site with a high-water level is, as a rule, more unhealthy than a site with a low-water level; but a site with a fluctuating water level is most unhealthy. The sanitary engineer can control the water level in the soil, or construct works to remedy the evils of a wet site. There is also a considerable quantity of carbonic acid in the soil. It varies at different depths; it has been found to vary greatly even in localities in close proximity. The processes going on in the soil in these several places are therefore probably very different, and each will have its influence on the ground air. One evil arising from a foul subsoil is very apparent. In cold weather the temperature of a house is warmer than that of the outer air. If a house is built on soil containing deleterious matters, the impure air will be drawn into the house by the action of the warm air of the house. The sanitary constructor takes measures to check the passage of air between the house and the ground under and around it. What can be more dangerous, what more wicked, than the everyday proceedings, in the metropolis and elsewhere, of those persons who purchase a building site, who extract from it the healthy clean gravel and sand which it contains, allow the hole to be filled up with rubbish, and then proceed to build upon it? When the site has been selected, the sanitary architect has to consider how he will distribute buildings over it. The deteriorating effect of residence in towns has been frequently noticed. It has been calculated that of the adult population of London, 53 per cent.; of that of Birmingham, 49 per cent.; of that of Manchester, 50 per cent.; and of Liverpool, 62 per cent. were immigrants from the country settled in the town, and that the majority of the incomers were men and women in the prime of life. The mortality in these four towns averaged 26 per 1,000, against 19 per 1,000 in the adjacent country districts, the mortality of persons under the age of fifteen being 40.7 per 1,000 in these towns, against 22 per 1,000 in th country districts. When we consider the causes of low health in towns, it becomes apparent that the extraordinary degree of unhealthiness is unnecessary. The superior healthiness of the model lodging houses is due in a measure to the careful provision of sanitary arrangements, but principally to the fact that the numerous stories in these buildings, whilst affording accommodation for a dense population on a limited area, are provided with free through ventilation, and allow of ample space all round for the circulation of air, as well as to the fact that impurities are not allowed to be retained in the open area round them. The next step in knowledge of sanitary construction is to learn how to obtain pure air in a building. What is pure air? What are the impurities which make the air of a town so different from the fresh air of the country? The volume of sulphurous acid from coal thrown up by our fires into London air is enormous. A cubic yard of London air has been found to contain 19 grains of sulphurous acid. The street dust and mud are full of ammonia, from horse dung. The gases from the sewers pour into the town air. Our civilization compels us to live in houses, and to maintain a temperature different from that out of doors. What are the conditions as to change under which we exist out of doors? The movement of the air is stated in the Registrar-General's reports to be about twelve miles an hour on an average, or rather more than 17 feet per second. It will rarely be much below 6 feet per second. In a room the conditions are very different. In barracks, in a temperate climate, 600 cubic feet is the space allotted by regulation to each soldier; and when in hospital, from 1,000 to 2,500 cubic feet to each patient. If it were desired to supply in a room a volume of fresh air comparable with that supplied out of doors, it would be necessary to change the air of the room from once to five times in every minute, but this would be a practical impossibility; and even if it were possible, would entail conditions very disagreeable to the occupants. Hence, to maintain the comfort and temperature we desire indoors, we sacrifice purity of air. Therefore, however impure the outer air is, that of our houses is less pure; and it may be accepted as an axiom that by the best ventilating arrangements we can only get air of a certain standard of impurity, and that any ventilating arrangements are only makeshifs to assist in remedying the evils to which we are exposed from the necessity of obtaining an atmosphere in our houses different in temperature from that of the outer air. On the other hand, why should we not do our best to obtain as pure air as we can? It has been recently shown that the soot and many deleterious matters from smoke may be easily removed by passing the smoke through spray on its way to the chimney. This would remove much impurity from town air; but until such a system of purifying town air is adopted, we can improve the air in our houses by removing the suspended matter from the inflowing air by filtration. Moreover, these suspended matters exist in much smaller quantities at an altitude; at 100 feet they are greatly diminished, at 300 feet the air is comparatively pure. In Paris, the air for the Legislative Assembly is drawn down from a height of 100 feet, so as to be taken from a point above many of the impurities of the town atmosphere. That is a reasonable and sensible arrangement, and might be usefully adopted in public buildings in towns. In the Houses of Parliament, the so-called fresh air is taken from courtyards on the street level, from which horse traffic is not excluded. It may be summed up, that whatever the cubic space, the air in a confined space occupied by living beings may be assumed to attain a permanent degree of purity, or rather impurity. One of the chief difficulties of ventilation arises from the draughts occasioned thereby. Every one approves of ventilation in theory, but practically no one likes to perceive any movement of air. The open fire-place creates circulation of air in a room with closed doors and windows. The air is drawn along the floor towards the grate; it is then warmed by the heat which pervades all objects near the fire, and part is carried up the chimney with the smoke, whilst the remainder, partly in consequence of the warmth it has acquired from the fire, and partly owing to the impetus created in its movement toward the fire, flows upwards towards the ceiling near the chimney-breast. It passes along the ceiling, and, as it cools in its progress towards the opposite wall, descends to the floor, to be again drawn towards the fireplace. Thus the open fire, whilst continually removing a certain quantity of air from the room, which must be replaced by fresh air, causes an efficient circulation of the air remaining in the room. Moreover, a room warmed by an open fire is pleasanter than a room warmed by hot-water pipes. A warm body radiates heat to a colder body near to it. The heat rays from a flame or from incandescent matter pass through the air without heating it; they warm the solid bodies upon which they impinge, and these warm the air. With complicated buildings, such as theatres, legislative assemblies, prisons, etc., the problems of ventilation are more difficult and intricate, but all are based on the same principles of the movement of air. Another group of questions relating to sanitary construction are: What are the best materials for the house, and the best distribution of those materials? How can the less pure air from the ground be prevented from entering the house through the basement? What is the effect of the porosity of materials on the health of the inmates of a house? What is the law which regulates the loss of heat through walls and windows, skylights and roofs? One instance of the sanitary importance of the quality of materials will suffice here. Dust and impurities adhere less to glass of a good quality than to glass of a bad quality. But there is one branch of work connected with water supply and drainage in which practical knowledge is especially necessary, and which has not been so prominently considered as it should be. I mean the details of the plumber's work, and the work connected with house-drains. However well you may design your house-drains, the whole of your design may be rendered nugatory by apparently trifling mistakes or carelessness in the details. Public attention has been so largely directed to water supply and drainage that I cannot refrain from offering a few remarks upon these subjects, which at the present time necessarily fill the public mind. We derive our whole water supply from rainfall. If it falls on an impervious surface, it runs off in rivers above ground; if it falls on a pervious surface, it runs off underground in rivers whose direction of flow will depend on the geological formation. However much our population may grow, we cannot, therefore, increase our supply; but we may store it and utilize it if we obtain a knowledge of where it falls and where it flows to. It is thus the function of the sanitary engineer to trace the course of these water supplies. But rain does not fall equally over the whole country. On the contrary, as has been so well shown by Mr. Symons, there is in some localities in England an enormous surplus, and in other localities a bare supply, and the incidence of these supplies has no reference to the spread of population over the country; thus it requires something beyond local organization to arrange for a distribution of the supply in accordance with the relative wants of the country. It is on these grounds essentially the duty of the Government to take up this question. The Government have taken into their hands the more thoeretical question as to when storms may be expected; but they have not taken in hand the question which has an enormously greater practical importance, viz., that of watching over our water supplies, although it is on the careful use of these that the health of the whole country depends. The first step towards obtaining a clear understanding of the question is to bring all the information on this subject to a focus.

At the present time there are certain important public departments, the information collected by which bears materially on the sanitary condition of the country; and yet these departments are scattered about indiscriminately, as if with the intention of preventing the information they already possess, and could so easily add to, from being brought to any useful focus. The departments to which I allude are,—first, the Ordnance Survey; second, the Geological Survey; third, the Registrar-General's Department; and fourth, the Meteorological Office. The first step is to bring these departments under one general head, so that the information they can severally afford may be properly correlated; and the Local Government Board would seem to be the department under which they would most naturally fall. On the question of sewage, time would not allow me to enter; it is sufficient to say that this must remain always a problem for the sanitary engineer, because no one system of sewage could be adopted universally; the peculiarities of different localities require different methods of treatment. Where land at a reasonable price can be procured, with favorable natural gradients, with soil of a suitable quality and in a sufficient quantity, a sewage farm, if properly conducted, is apparently the best method of disposing of water-carried sewage. In the case of towns where land is not readily obtained at a moderate price, some of the processes, based upon subsidence, precipitation, or filtration, produce a sufficiently purified effluent for discharge, without injurious results, into watercourses and rivers, provided the volume of water into which it is discharged is of sufficient magnitude to effect a considerable dilution. But, as a rule, no profit can be derived at present from sewage utilization. My object in this *résumé* has been to endeavor to show how extensive is the field of knowledge which has to be traversed by those who undertake the duty of building healthy houses, and of watching over the arrangements for securing the health of towns. The acquisition of sanitary knowledge covers a vast area of ground, and requires special study. The universities of Oxford, Cambridge, and London instituted examinations in public health, but with little success; few candidates came forward, and indeed no candidates offered themselves for Oxford or London at the last examination. Until some means of obtaining the education can be afforded, it is of little avail to establish examinations, or to offer to give degrees. The Sanitary Institute, whose *raison d'être* is to promote sanitary progress, has from the first recognized the importance of developing sanitary education, and has now decided to come forward as its champion. With this object, the Sanitary Institute proposes to organize a course of lectures to be delivered in the practical branches of this question during the coming winter, and in this effort which they are about to make for the public good, the Council trust they will receive the support of all those interested in sanitary progress. There is, however, a further step required in order to produce throughout the country a due recognition of the importance of sanitary knowledge, and this step should be at once taken. The medical officers of health, who are the advisers of the local authorities on questions connected with public health, have obtained a title to their position in the medical profession, by virtue of certificates from qualified Boards of Examiners. But local surveyors, whose duty it is to advise local authorities on matters of sanitary construction, are not required to produce any such certificate of qualification. The summary of the conclusions to which I would lead you in this address are, therefore—1. That endeavors should be made to cause the adoption in educational establishments of courses of systematic education in sanitary science for those who undertake the business of sanitary construction. 2. That no person should be appointed to the office of surveyor of a Local Board or Corporation, without a certificate from some duly-qualified educational institution of proficiency in practical sanitary science.

A NEW bridge over the Burdekin river, Northern Queensland, on the road to Charters Towers, has just been completed, and is worthy of mention as being one of the largest in the colony; it is 1200 feet from end to end, with the exception of two spans over the waterway, which are 45 feet and 25 feet respectively; the whole of the bridge consists of 20 feet spans, the main girders and headstocks being of hard wood, 14×14, and the piles, which are concreted 4 feet into the rock, having a diameter of 17 inches at base. The work has been carried out by Messrs. Watson & Johnson, under the superintendence of Mr. M'Millan, the engineer for roads and bridges, Northern Division.

ON TOPOGRAPHICAL SURVEYING.

By GEO. J. SPECHT, C. E.

Written for VAN NOSTRAND'S MAGAZINE.

THE object of Topography is to determine the relative positions of points of the earth's surface, that can be referred without error to a tangent plane, and therefore independent of the sphericity of the globe.

The operations of a topographical survey, consequently, are two—namely, to first project a system of points upon such a tangent plane; and, secondly, to find the distances of the same above or below the plane; or, in other words, to measure the lengths of the projecting normals. The first process is ordinary surveying, the second, leveling.

The results of a topographical survey are laid down in a so-called topographical map, which is a representation or complete image of the ground on a reduced scale.

Topographical maps are of the greatest convenience in locating railroads or other roads, in planning irrigation works, draining works, in mining enterprises, in military operations, &c., &c. In a topographical map the configuration of the ground is reduced to an image, which represents to the eye a large area at one glance, which in nature could not be viewed but by many separate inspections; therefore, the judgment about the relation of the different parts of the work will be a clearer and more intelligent one. This refers especially to mining work, where very frequently the problem occurs, to strike a vein with a tunnel in a certain level. In this problem a correct topograghical map will often save the mining company several hundred feet of tunnel work, or in other words thousands of dollars.

One reason why topographical surveys are not oftener made, is certainly the slowness on one hand and the inaccuracy on the other hand of the old methods.

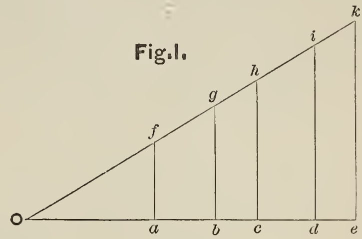
Two different methods have heretofore been employed; one has the great disadvantage of slowness, and the other that of being unreliable. The first is a combination of common surveying with leveling. Provided these two operations are carried out with all possible care, the work will be a very exact one; which, however, will partly be lost by the inaccuracy of the drawing. Therefore, in this method, the field-work is unnecessarily superior to the requirements of the case, as the reduced scale of a topographical map does not allow the representation of the smaller details. And as the topographical map is the first and direct object of a topographical survey, the latter ought not to be more exact than the scale of the map requires; for instance, if the map is made on a scale of 1.5000 ($1''=416.6'$), the distances on the map can be read or estimated with any certainty only within four feet. Consequently, the survey does not need be more detailed than to correspond to this limit. The second method is also a combination of common surveying with leveling, yet in a more hurried and therefore unreliable manner; it is on ground of a measured and leveled base to sketch the surroundings. As a matter of course the correctness of a topographical map, derived from such a survey, depends entirely on the ability of the topographer to estimate the relations between the different points. And as there are too many sources of error such topographical maps are but little value; they render good service in military reconnoissance, but hardly anywhere else.

Without going into the details of the old methods (which are shortly treated in Gillespie's Handbook), I shall proceed at once to give an account of the new method of topographical surveying. The word "new" is justified only in view of the two above-mentioned methods, as the one to be described has been known since 1852, when the Italian Professor and Officer of Artillery, Porro, of Milan, gave an account of this method *Annales des Ponts et Chaussées*; and when also the French engineer, Minot, published a treatise on this subject. The French and the Italians were the first who used it; then it came largely into use in Switzerland, where, in connection with the plane table, it was and still is used for the beautiful and masterly-executed topographical maps of Switzerland, in a scale of 1.50,000, with contour lines of 30 meters distance. Austria and Germany followed next, and are using it largely in railroads and similar enterprises. To-day it is used in those countries wherever any work of that kind is done; the Prussian General Staff employs it nearly exclusively. When and to what extent it was introduced in the United States is not known to the writer, but the note of A. S. Hardy, Professor of Civil Engineering in the Chandler Scientific School, in VAN NOSTRAND'S ENGINEERING MAGAZINE, Aug., 1877, indicates that this method was hardly known, for otherwise he would not have praised the old, old method, he mentions, as quite a new application of contour lines. The United States Coast Survey uses this new method extensively in connection with the plane table.

THE NEW METHOD

of topographical surveying consists in simultaneously obtaining the horizontal and vertical positions of a point; in other words, each point is determined by *one* operation in reference to its horizontal and vertical location. This is accomplished by the use of a transit with the so-called stadia wires and a vertical circle, and a leveling rod or so-called telemeter or stadia-rod.

Besides the ordinary horizontal and vertical cross hairs of the diaphragm of the telescope, two extra horizontal hairs are placed parallel with the center one, and equally distant on each side of it, which, if the telescope is sighted at a leveling rod, will inclose a part of this rod or stadia-rod, proportional to the distance from the instrument to the rod. By this arrangement we have obtained an angle of sight, which remains always constant. Supposing the eye to be in the point O (Fig. 1), the lines O e and



O k represent the lines of sight from the eye through the stadia-wires to the rod, which stands consecutively at $k\,e$, $i\,d$, $h\,c$, $g\,b$ and $f\,a$. According to a simple geometrical theorem we have the following proportion:

$$O\,a : O\,b : O\,c : O\,d : O\,e = a\,f : b\,g : ch : d\,i : e\,k,$$

which means that the reading of the rod placed on the different points a, b, c, d and e is proportional to the distances O a, O b, O c, O d and O e.

The system of lenses which constitute the telescope do not allow the use of this proportion directiy in stadia measurements, because distances must be counted from a point in front of the object glass at a distance equal to the focal length of that lens.

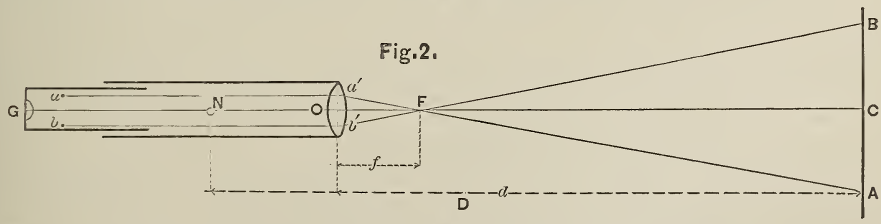


Fig. 2 represents the section of a common telescope with but two lenses, between which the diaphragm with the stadia-wires is placed.

We assume:

f = the focal distance of the object glass.
p = the distance of the stadia-wires a and b from each other.
d = The horizontal distance of the object glass to the stadia.
a = stadia reading (B A).
D = horizontal distance from middle of instrument to stadia

The telescope is leveled and sighted to a leveling or stadia rod, which is held vertically, hence at a right angle with the line of sight. According to a principle of optics, rays parallel to the axis of the lens, meet after being refracted in the focus of the lens. Suppose the two stadia wires are the sources of those rays, we have, from the similarity of the two triangles, a' b' F and F A B the proportion:

$$(d-f) : a = f : p.$$

The value of the quotient, $f : p$, is, or at least can be made, a constant one, which we will designate by the letter k; hence we have:

$$(d-f) = \text{F C} = k\ a.$$

In order to get the distance from the center of the instrument N, we have to add to the above value of F C yet the value c.

$$c = \text{O F} + \text{O M}.$$

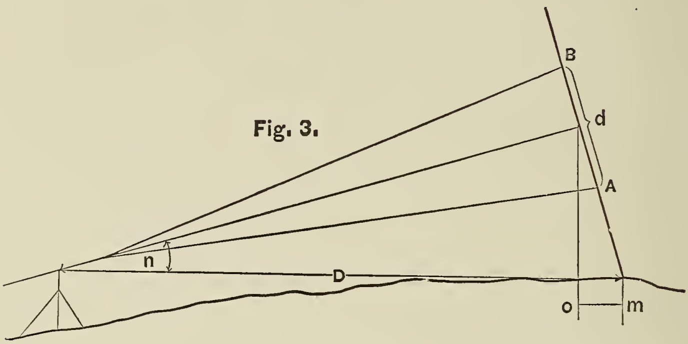
O M is mostly equal to half the focal length of the object, hence we have

$$\text{C} = f + f_2 = 1.5\,f.$$

Therefore the formula for the distance of the stadia from the center of instrument, when that stadia is at right angles to the level line of sight, is:

(1) $$\text{D} = k.a + c.$$

Fig. 3.



When the line of sight is not level, but the stadia held at right angle to it, the formula for the horizontal distance is:

(2) $$\text{D} = k.a.\cos n + c + om.$$

The member $\overline{om} = \frac{a}{2} \sin n$; for $a = 24'$, $n = 45°$ the value of $\overline{om}$ is but $8.4'$, and for $a = 10'$, $n = 10°$ it is $0.86'$; this shows that $\overline{om}$ in most cases may safely be omitted.

Some engineers let the rodman hold the staff perpendicular to the line of sight; they accomplish this by different devices, as, a telescope or a pair of sights attached at right angle to the staff. This method is not practicable, as it is very difficult, especially in long distances, and with vertical angles for the rodman to see the exact position of the telescopes, and furthermore, in some instances it is entirely impossible, when, for instance, the point to be ascertained is on a place where only the staff can stand, but where there is no room for the man. The only correct way to hold the staff is vertically.

In this case we have the following: (Fig. 4)

$\text{MF} = c + \text{GF} = c + k.\text{C.D}$

CD must be expressed by AB.

$\text{AB} = a. \quad \text{AGB} = 2m.$

$\text{CD} = 2\text{GF}\tan.m.$

By the similarity of the two triangles AGF and BGF, we have after some transformations

$$\text{AF} + \text{BF} = \text{GF}\sin m \left(\frac{1}{\cos(n+m)} + \frac{1}{\cos(n-m)}\right)$$

$$\text{GF} = \frac{\text{CD}}{2\tan m}, \ \text{AF} + \text{BF} = a$$

$$a = \text{CD}. \frac{\cos m.\sin m \cos(n-m) + \cos(n+m)}{2\sin m.\cos(n+m)\cos(n-m)}$$

$$\text{CD} = a\frac{\cos^2 n\cos^2 m - \sin^2 n \sin^2 m}{\cos n \cos m.}$$

$$\text{MF} = c + \text{GF} = c + k.\text{CD}.\text{MF} = \frac{\text{D}'}{\cos n}$$

$$\frac{\text{D}}{\cos n} = c + k.a\frac{(\cos^2 n\cos^2 m - \sin^2 n \sin^2 m)}{\cos n \cos^2 m}$$

$$\text{D} = c.\cos n + a.k.\cos^2 n - a.k.\sin^2 n \tan^2 m.$$

The third member of this equation may safely be neglected, as it is very small even for long distances and large angles of elevation (for 1500′, $n=45°$ and $k=100$, it is but 0.07′). Therefore, the final formula for distances, with a stadia kept vertical, and with wires equidistant from the center wire, is the following:

(3) $$D=c.\cos n+a.k.\cos^2 n.$$

The value of $c.\cos n$ is usually neglected, as it amounts to but 1 or 1.5 feet; it is exact enough to add always 1.25′ to the distance as derived from the formula

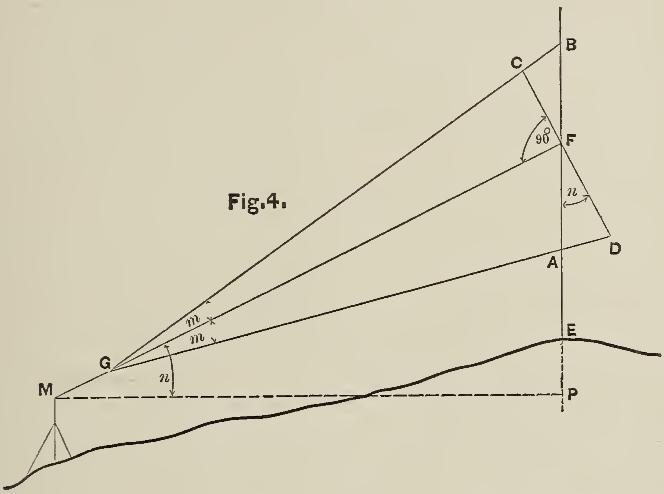
(3a) $$D=a.k.\cos^2 n$$

without considering the different values of the angle n.

In order to make the subtraction of the readings of the upper and lower wire quickly, place one of the latter on the division of a whole foot and count the parts included between this and the other wire; this multiply mentally by 100 (the constant k) which gives the direct distance d'.

In cases where it is not possible to read with both stadia wires, it is the custom to use but one of them in con-

Fig.4.



nection with the center wire, and then to double the reading thus obtained. With very large vertical angles, this custom is not advisable, as is shown by the following theoretical investigation:

Take the same figure 4 as above

$$BF=\frac{BG\sin m}{\sin(90°+n)};\quad AF=\frac{AG\sin m}{\sin(90°-n)}$$

$$BF=\frac{GF.\sin m}{\sin(90°-m-n)};$$

$$AF=\frac{GF.\sin m}{\sin(90-m+n)}$$

$$\frac{BG\sin m}{\sin(90°+n)}=\frac{GF\sin m}{\sin[90°-(n+m)]}$$

$$\frac{BG}{\cos n}=\frac{GF}{\cos(n+m)};\quad BG=\frac{GF\cos n}{\cos(n+m)};$$

$$GA=\frac{GF\cos n}{\cos(n-m)}$$

$$\therefore BG:AG=\frac{GF\cos n}{\cos(n+m)}:\frac{GF\cos n}{\cos(n-m)}$$

$$BG:AG=\cos(n-m):\cos(n+m)$$

$$BF:(BF+AF)=\cos(n-m):[\cos(n-m)+\cos(n+m)]$$

$$AF:(BF+AF)=\cos(n+m):[\cos(n+m)+\cos(n-m)]$$

$$\frac{BF.2\cos n\cos m}{\cos n\cos m+\sin n\sin m}=\frac{AF.2\cos n\cos m}{\cos n\cos m-\sin n\sin m.}$$

$$\frac{BF\cos n\cos m}{\cos n\cos m}-\frac{BF\sin n\sin m}{\cos n\cos m}=\frac{AF\cos n\cos m}{\cos n\cos m}+\frac{AH\sin n\sin m}{\cos n\cos m}$$

$$BF(1-\tan n\tan m)=AF(1+\tan n\tan m)$$

$$BF=\frac{a}{2};\quad AF=\frac{a}{2}$$

Now if we multiply one of these values with 2, we see that the result is not equal to a, but equal to $a \pm a \tan n \tan m$; hence the distance D is either too long or too short by the amount of $a.k.\cos^2 \tan n \tan m$; for $a=15'$, $n=45°$ and $k=100$, the distance measured with both stadia wires is 749.7,′ but as measured with only one stadia wire and the center wire, we have either 753.4′ or 746.0′, which is an error of 0.50%; for $a=15'$, $n=22°$ and $k=100$, we have correct distance=1289.1′, distance with one wire, either 1286.5′ or 1291.7′, which is an error of 0.25%.

To find the height of the point where the stadia stands, simultaneously with the distance, we have the following:

We assume, in reference to figure 4,

q=height of instrument point above datum.

MP=D=horizontal distance as derived from formula (3).

n=vertical angle.

h=FE=stadia reading of the center wire.

Q=height of stadia point above datum; it is,

$$Q = q + D \tan n - h.$$

The subtraction of h can be made directly by the instrument, by sighting with the center wire to that point of the rod, which is equal to the height of the telescope above the ground (which is in most cases=4.5′); q will be constant for one and the same instrument point; then the above formula:

$$Q = D \tan n;$$

this in connection with formula (3) gives

$$Q = c \sin n + a.k. \cos n. \sin n.$$

or

$$Q = c \sin n + a.k. \frac{\sin 2n}{2}$$

The first form of the equation can be neglected, when the vertical angle is not too large; hence the final formula for the height is

$$\text{(5)} \qquad Q = \frac{a.k. \sin 2n}{2}$$

The position of the stadia must be strictly vertical.

Without giving here the theoretical investigation of the manner in which an inclination of the stadia towards or from the instrument affects the distance, I shall mention but the results of the investigation on this subject. The following table is calculated from a formula given by Professor Helmert, of the Royal Polytechnic School in Aachen (Germany):

$$D - D' = \pm \tfrac{1}{2} k \sin 2n \sin o \sqrt{2m^2 + \frac{a^2}{2}},$$

where D is the reading at a stadia exactly vertical.

D′ is the reading at a stadia not vertical.

k=the constant, n=vertical angle, o=angle of inclination of the stadia when not held exactly vertical, m=height of the center wire, and a=stadia reading.

The table is calculated for $k=100$, $\sin o=0.01$, and for $m=1'$, 4.5′ and 10′.

n.		a= 2.0	3.0	4.0	5.0	6.0	8.0	10.0	12.0
10°	1.	0.34	0.43	0.54	0.62	0.76	0.99	1.22	1.46
	4.5.	1.10	1.12	1.18	1.24	1.30	1.42	1.62	1.89
	10.	2.42	2.43	2.46	2.48	2.51	2.59	2.70	2.80
20°	1.	0.64	0.32	1.01	1.18	1.43	1.88	2 32	2.76
	4.5.	2.08	2.16	2.23	2.33	2.25	2.72	3.06	3.56
	10.	4.57	4.60	4.65	4.68	4.79	4.82	5.10	5.28
30°	1.	0.87	1.11	1.37	1.59	1.93	2.53	3.13	3.72
	4.5.	2.82	2.92	3.01	3.14	3 31	3.68	4.13	4.80
	10.	6.18	6.20	6.26	6.31	6.38	6.60	6.85	7.15
40°	1.	0.98	1.25	1.55	1.81	2.20	2.88	3.56	4.22
	4.5.	3.19	3.30	3.41	3.58	3.77	4.18	4.68	5.45
	10.	7.00	7.05	7.11	7.18	7.25	7.49	7.80	8.12

The error increases with the height of *m*.; in shorter distances the result is sevenfold better when the center wire is placed as low as one foot than it is at 10′; in longer distances this advantage is only double.

It is always better to place the center wire as low as possible. If the stadia is provided with a good circular level, the rodman ought to be able to hold it vertical within 500 seconds; that means, that the inclination of the stadia shall not be more than 0.023′ in a 10′ stadia, or 0.034′ in a stadia of 15′ length.

DETERMINATION OF THE TWO CONSTANT COEFFICIENTS *t* AND *k*.

Although the stadia wires are usually arranged so that the reading of one foot signifies a distance of 100 feet, I will explain here, how to determine the value of it for any case. Suppose the engineer goes to work without knowing his constant, and not having adjustable stadia wires. The operation then is as follows:

Measure off on a level ground a straight line of about 1000′ length; mark every 100′, place the instrument above the starting point, and let the rodman place his rod on each of the points measured off; note the reading of all three wires separately, repeat this operation four times; the telescope must be as level as the ground allows; measure the exact height of the instrument, *i. e.*, the height of the telescope axis above the ground. Then find the difference between upper (*o*) and middle (*m*) wire; between middle (*m*) and lower (*n*) wire, and between upper (*o*) and lower (*n*) wire, from the four different values for each difference, determine the average value; then solve the equation for the horizontal distance (1) $D = k.a. + c.$, with the different average values, and you find the value of *k* and *c*. In case the stadia wires should not be equidistant from the center wire, there will be three different constants, one for the use of the upper and middle, one for the use of the middle and lower, and one for the upper and lower wire. The following example, which occurred to me, will explain these rules: (the measures are meters, which, of course, makes no difference).

Number of Observations.	Distance Measured.	Stadia Readings.			Differences.			Angle of Elevation.	Height of Instrument.
		o.	*m.*	*u.*	*o—m.*	*m—u.*	*o—u.*		
	Meters.								
1.	25	1.503	1.300	1.117	0.203	0.183	0.386	0° 32′	1.318
	50	1.503	1.100	0.727	0.403	0.373	0.776		
	75	1.810	1.200	0.640	0.610	0.560	1.170	1° 0′	
	100	1.915	1.100	0.355	0.815	0.745	1.560		
	115	1.940	1.000	0.140	0.940	0.860	1.800	1° 2′	
2.	115	1.940	1.000	0.140	0.940	0.860	1.800		
	100	1.915	1.100	0.350	0.815	0.750	1.565		
	75	1.810	1.200	0.640	0.610	0.560	1.170		
	50	1.507	1.100	0.730	0.407	0.370	0.777		
	25	1.700	1.500	1.316	0.200	0.184	0.384		
3.	25	1.502	1.300	1.116	0.202	0.184	0.386		1.318
	50	1.504	1.100	0.730	0.404	0.370	0.774		
	75	1.812	1.200	0.642	0.612	0.558	1.170		
	100	1.915	1.100	0.355	0.815	0.745	1.560		
	115	1.940	1.000	0.140	0.940	0.860	1.800		
4.	115	1.937	1.000	0.140	0.937	0.860	1.797		
	100	1.915	1.100	0.355	0.815	0.745	1.560		
	75	1.810	1.200	0.640	0.610	0.560	1.170		
	50	1.505	1.100	0.728	0.405	0.372	0.777		
	25	1.701	1.500	1.315	0.201	0.185	0.386		

The base was 115^m long.

Out of these observations, we derive the following means:

Distances.	Differences.		
	o—m.	*m—u.*	*o—u.*
24	0.201	0.184	0.385
50	0.405	0.371	0.776
75	0.610	0.560	1.170
100	0.815	0.746	1.561
115	0.939	0.860	1.799

The different values of these differences, applied to the formula for horizontal distances, (the angle of elevation is so small that it need not be considered),

$$D=k.a+c,$$

we have the following fifteen equations:

Equations for $(o—m)$

$$\text{I.}\begin{cases}25^m=0.201\ k+c.\\50^m=0.405\ k+c.\\75^m=0.610\ k+c.\\100^m=0.815\ k+c.\\115^m=0.939\ k+c.\end{cases}$$

Equations for $(m—n)$

$$\text{II.}\begin{cases}25^m=0.184\ k+c'.\\50^m=0.371\ k+c'.\\75^m=0.560\ k+c'.\\100^m=0.746\ k+c'.\\115^m=0.860\ k+c'.\end{cases}$$

Equations for $(o—n)$

$$\text{III.}\begin{cases}25^m=0.385\ k+c''.\\50^m=0.776\ k+c''.\\75^m=1.170\ k+c''.\\100^m=1.561\ k+c''.\\115^m=1.799\ k+c''.\end{cases}$$

By solving these equations, we obtain the following average values for the constants k and c, k' and c', k'' and c''.

For the group I we have;

$$k=122.30, \quad b=0.40.$$

For group II:

$$k=133.30, \quad b'=0.45.$$

For group III:

$$k''=63.70, \quad b''=0.50.$$

This example shows one of the most unfavorable cases, as we obtain three different values for each of the two constants, because the stadia wires are not equi-distant from the center-wire. If the stadia wires are adjustable, the engineer has it in his power to adjust them so that the constant $k=100$, and $k_2=200$, which he accomplishes by actual trial along a carefully measured straight and level line.

The constant C, which is one and a half times the total length of the object-glass can be found closely enough for this purpose by focussing the telescope for a sight of average distance, and then measuring from the outside of the object-glass to the capstan-head-screws of the cross-hairs. This constant must be added to every stadia sight; it may be neglected for longer distances.

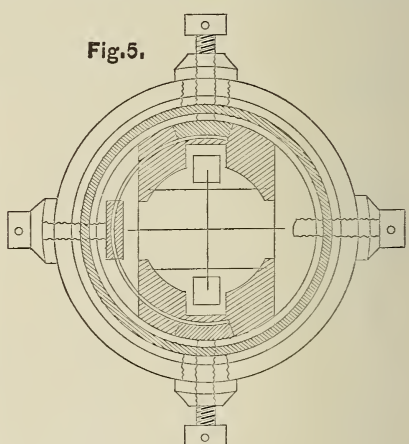
THE INSTRUMENTS

used in this method are the following.

1, a transit or theodolite, which in general construction is like the common one; the only new features of it are the stadia wires and the vertical arc.

The diaphragm carrying the cross wires has two sides, which can be moved by small capstan heads crews, and on each end of which one stadia wire is fastened;

Fig.5.



an inserted spring makes their position more steady. By means of those screws the distance of the stadia wires from the centre wire, and from each other can be adjusted at will.

For stadia measurement it is far preferable to use a telescope with inverting eyepiece as they allow a longer distance to be read; the little inconvenience at first of seeing the objects inverted, will very soon be overcome, and the engineer will gladly adopt it, because it enlarges the range of his work so advantageously. Light and magnifying power are the essential points for a telescope used in stadia measurements, more than in any other branch of surveying. Therefore, the telescope ought to have none but the two-lens negative eye-piece, which inverts the objects. The so called Kellner's orthoscopic eye-piece should be used (Fig. 6); it is completely achromatic,

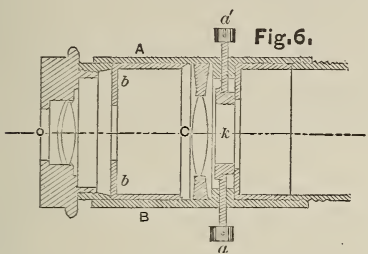


Fig. 6.

and has the great advantage, which no other eye-piece has, of an actually flat field and a straight flat image of any object, correct in perspective, distinct in its whole extent. It consists of three lenses, the bi-convex collective lens C, the flatter curve of which is towards the object-glass, and the achromatic lens O, which is composed of two lenses, similar to the achromatic object-glass. The diaphragm *b*, *b*, is a further peculiarity of this eye-piece Messrs. Buff & Berger in Boston use such eye-pieces in their instruments.

The vertical arc must be larger than usual, so as to allow of a vernier reading of at most one minute. In order to make no mistakes in reading the vertical angle, whether it be an angle of elevation or depression, the numbering of the vertical arc must be so arranged that the zero point of the arc corresponds with the zero of the vernier, when the telescope is level, and the numbers go from 0° to 360°. By this arrangement the observer knows at once whether the angle is an angle of depression or one of elevation, without using the signs of minus or plus. The now very often preferred arrangement of making the vertical arc fixed, and the vernier movable with the telescope is far inferior to the fixed vernier and the movable arc

A transit or theodolite fitted out in this way is called a tachometer, which means "quick-measurer," and hence this method is "tachometric."

The next instrument essential to the topographical survey is the rod or stadia rod or telemeter; this is a self-reading leveling rod, with a graduation fit to be read at a long distance. A good rod must have the following qualities:

1. It must be light and handy for transportation.

2. The graduation must be distinct and visible at long distances; it is not to be closer than one-tenth of a foot, as otherwise the reading would become confusing for longer distances. Experience teaches that smaller subdivisions can more exactly be estimated than read by a direct division.

3. It must have a good and reliable arrangement to enable the rodman to keep it in the required position.

It is advantageous to add a target to the rod, which is used but for the most important points, especially at new stations for the instrument.

The rod consists of two or more parts, which are either entirely separated during the transport and put together by means of screws or otherwise, when used, or they are connected with each other by hinges, or are made to slide in or along each other. I am using one which consists of three separate pieces, each 5 feet long and of a cross section, as shown in figure 7; the ends are protected by iron shoes; the pieces are joined by screws. On the back is a circular level. (Fig. 8).

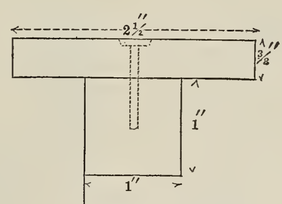


Fig. 7.

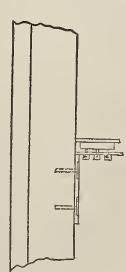
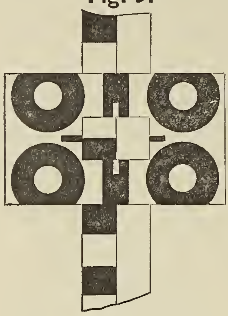


Fig. 8.

As to the pointing of the rod, the two styles shown in Figs. 10 and 11 are very practical. The alternative position of the feet makes the reading a great deal easier and the whole graduation much more distinct. Fig. 11 represents a so-called "combination rod," which can serve as a common leveling rod by means of the small subdivisions. The largest I use is represented in Fig. 9; it slides

Fig. 9.

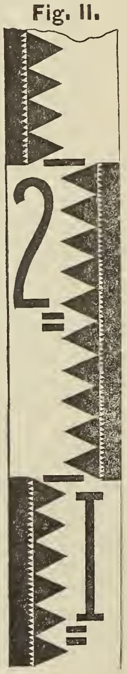


along the small edges of the rod; the circles do not touch each other, but are yet so close that the exact center of the target can be estimated very exactly; it has no vernier, which, however, could easily be attached.

In order to save a second target, the

Fig. 10.

Fig. 11.



end of the stadia is shaped as shown in Fig. 12, so making it a stationary target. The colors to be used are best either black and white, or red and white; red has the advantage that the cross wires can be distinguished on it, which they cannot on a black division. The white ought to have a light yellow shade.

These are the instruments used in the stadia method of topographical surveying. Now, I shall describe the mode and manner of working; I have to make the distinction between work done with the tachometer and work done with the plane-table.

For railroad surveys, with the tachometer, the field party must consist of two engineers, one assistant, two rodmen, who serve at the same time as flagmen and eventually as chainmen, one or two axmen. The engineer in charge of the

Fig. 12.

party, after a general reconnoissance of the country, selects the points upon which the rodmen have to place their stadia; he makes sketches of the general lay of the country in his field book, and numbers the points in his book as taken by the stadia. Goldschmidt's Aneroid will be a good companion for him.

The purpose of the work and the scale of the topographical map—if such is to be made—determines the number of points to be taken. In railroad work it will generally suffice to take as many points as will enable the engineer to make an intelligent estimate of the amount of earthwork to be done, and to make accordingly changes of the line in his map without going anew into the field. The engineer in charge of the instrument places the same over the initial point, which is chosen so that as large a field as possible can be seen from it, without regarding whether it is in the probable future line. One of the rodmen takes all points to the left, the other all those to the right of the instrument; it is a matter of course that the rodmen must be quite intelligent and well instructed. The assistant has charge of the field book and writes down the readings which the engineer calls out. He also gives the signals to the rodmen as directed by the engineer, and, if time permits, makes the necessary calculations. Some engineers do away with this assistant, but the employment of one expedites the work to a great extent.

A good and distinct system of signals between engineer and rodmen is very essential. In order to avoid confusion, each tenth point of each rodman is indicated by them by a signal; also roads, trails, creeks, and similar objects must be marked in a similar manner. Where only one rodman is employed, a whistle or little trumpet will suffice; when two or more rodmen are at work each must have his own style of signal.

Two, or at the most three, rodmen are plenty to keep the engineer and one assistant busy.

In order to avoid mistakes the rodman, who is not sighted at, but has already arrived at his new point, should uot put up his staff in correct position before he hears the signal, which allows the other one to move, but must keep it in an inclined position, being ready to place it correctly as soon as required. A well understood code of signals is a very important point.

After a sufficient number of points has been taken, one of the rodmen goes to the engineer in charge, who selects the next point for the instrument, which he must select in reference to a good foresight and in understanding with the engineer on the instrument, as the latter must give the correct grade by setting his telescope at a vertical angle corresponding to the grade the road shall have. Here the rodman uses the target. After such a point has been selected, the instrument is removed to it. Meanwhile, the second rodman has returned to the former instrument point and placed his rod with the target on it; after the engineer has taken his back sight to this point and checked by it his first stadia reading, the rodman comes to him and they proceed as before.

That disturbances in the position of the telescope may be detected and accordingly taken into account, it is advisable to sight at the beginning of the work at a fixed and well marked point, as a house corner or any other well defined object, and to sight at it again at the end of the work before removing the instrument to the next point. This is a check which ought never to be neglected.

In order to determine the distance between the two instrument points as exactly as possible, and to free the same of all instrumental errors, the readings for those points must be done in both positions of the telescope. The horizontal angles for those points must be read not only with the needle, but also with both verniers; this also ought to be done for the determination of houses, bridges, or other important points. If the instrument has a repeating circle, it is advantageous to place the zero point of the verniers on the zero point of the limb, when the telescope is pointed to the preceding standpoint.

An other precaution, to guard against errors in the distances, is, to determine two or three points in the line about half way between the two stand points, which are sighted at from either one. By this, two measurements of the distance are obtained, each independent of the other, thus giving a very good check

The method as described above, of course, allows many variations; each engineer will soon form his own style of working; so, for instance, if good, reliable and intelligent rodmen are to be had, one engineer for the whole party will be sufficient; the progress perhaps will be a little slower, and then besides, the above method has the advantage, that the engineer in charge has an opportunity to make himself thoroughly acquainted with the ground, to make valuable sketches and notes.

The proceeding in a topographical survey for other purposes than railroads, must be a little different, according to the space to be embraced. For railroad survey, only, but a narrow strip of land on both sides of the line is required; but for mining, irrigating and similar purposes the field to be surveyed is of larger extent. Therefore, the following proceeding is advisable. First select a sufficient number of points all over the country to be surveyed, which shall be the future points of the instrument. Select those points so, that at least two other points can be sighted at from each, and that as large an area of ground can be surveyed from it as possible. Secure them with good, solid monuments; then make a triangulation of those points (which operation sometimes may be combined with the actual topographical survey), and determine their heights by a careful leveling. After this proceed with the topographical survey as described before.

This method, of course, is comparatively slow, but gives most satisfactory results, as the work is constantly checked by the triangulation and leveling, which was done independently of the topographical survey; it is the best method for all mining and irrigation enterprises and, generally speaking, for all undertakings, where permanency of the works is contemplated, and where during the course of the survey some engineering work is in progress. Here, those points, trigonometrically determined and well served by good monuments, will always serve as reliable points of reference and check; they are of permanent value.

Sometimes it will suffice to determine only a limited number of trigonometrical points, but well selected, so that they can be seen from a great many points in the field to be surveyed; then the instrument points are determined in reference to them. This method will prove most convenient with the plane table, as the points then can be determined by the three-point problem.

Although most engineers will make their own blanks of field book, to suit their views and customs, I give here a blank, which has served a good purpose.

No. of instrument, point and height of telescope above datum.	No. of the point sighted at	Vernier reading on the horizontal limb.		Vertical.	Stadia reading of			Difference.	Reduced distance.	Height of point above or below telescope axis.	Height of point above datum.	Remarks.
		Vernier I. also Needle reading.	Vernier II.	Angle	Middle wire. (m)	Upper wire. (o)	Lower wire. (u)	$o-u$		$\pm$		

The stadia method, heretofore described in connection with the tachometer, is still more useful with a plane-table.

The alidade is profitably provided with a so-called parallel ruler, which contributes a great deal to the quickness of the work, and—although not correct from a theoretical point of view—is quite exact enough for the work usually required.

The compass box must be a rectangular one to allow a line to be drawn along its edge. By this, the North line is directly drawn upon the paper. After a sheet is filled, or the work finished, it is advisable to draw the scale on the sheet itself, so that the changes of the paper shall not introduce error.

For all further particulars about the plane table, I refer to the book published by the U. S. Coast Survey on this subject, and, for the adjustments of the instruments, I refer to the catalogues of the different makers.

I will now refer to those topographical maps in which the topography is represented by means of constant lines. To use the words of Professor L. M. Haupt: "This method of representing topography is vastly superior to any other, as it exhibits exactly the slope of any portion of the ground, gives the elevation of the base of any object within the tract, enables one to make vertical sections in any direction with accuracy from the plot, and so locate roads, paths or other features upon a given grade or at any desired elevation, and furnishes the means of calculating the contents of irregular solids with great precision."

A contour line is a line which connects all points of one and the same height with each other; therefore, their nearness or distance on the maps indicate the steepness or gentleness of the slopes; the nearer together, the steeper, and the more distant from each other, the gentler is the slope of the country represented.

Although not exactly belonging to the subject of this treatise, I will say a few words about railroad locating generally. These are suggested by some remarks of Arthur M. Wellington, C. E., in the introduction to his highly interesting book, "The Economic Theory of Location of Railroads." He says, page 18, and following:

"Another inevitable consequence of such general neglect is that this intricate science of design has been degraded in popular esteem, and even in the minds of engineers, who ought to know better. In former times the ablest engineers gave personal and unremitting attention to the work of location, but we have changed all that at the present day. As soon as a young man has acquired some facility in transit work, and has some glimmering notion that curves and grades are very objectionable evils—or are *not* very objectionable evils, depending on whom he "ran transit" for—he is forthwith a locating engineer, and he is such in fact in so far as this, that further practice will teach him nothing. For after making one or two surveys he will have mastered the mechanical process of handling a party, and begin to look down on the work of location—because he knows nothing about it. His work is the dead corpse of location, beginning and ending in the transit. If he is a rising man he will soon find some other young man to take his place in the field, and do the *really important* work, and very probably begin that vicious system of office-location from contour maps which has ruined the alignment of so many railways. Now, all this is especially calamitous, for it is almost a certainty that any one who has not a thorough *theoretical*, as well as practical knowledge of location, will fail entirely to catch the governing features of the region traversed, and find the line which has probably been lying there since time began. The instances are almost innumerable where young men—and old men—of this class have run over and under and across a line of the highest operating value, and turned in a costly and miserable line at last. And the contour-map system does not help this evil even in the hands of a thoroughly capable engineer; for the contour map is simply a device for doing ill in the office, the simplest part of the work, viz.: the first approximation to the adjustment of the line in detail; and its most effectual office is, to deaden the perceptive faculties of the engineer in charge of the party and transform him into a mere machine. Of what value is a contour map of an ill-judged line? The truly difficult part of location is the selection of the general route and the final ultimate perfection of its adjustment in detail; and the engineer who can do *this* work well will thank no one for the rude assistance of a contour-map location, made without the detailed familiarity with the ground which is gained by tramping over it. In fact, he will approximate to the detailed alignment quite as well and as rapidly without any such assistance, simply by feeling his way upon the ground, profile in hand, and his party behind him, and guided by a few notes from a rough plot. Nor will such an engineer, if he have a true feeling for the dignity and importance of his work, be content with making some contour-map guesses to be tested by less skilled subordinates. If he is to interfere in any way and his judgment have any value on paper, it is worth more upon the ground; and there is where he ought to be. He will detect more possibilities while sitting on the fence in apparent idleness than by the longest study of maps, and however long his experience or brilliant his ability, he can at no time in his professional career have more important financial interests depending on a chance inspiration. It should be more generally recognized that the place for the ablest engineers, which money will command, is not in the office or on construction, but in the field at the head of the locating party.

"A large part of this evil is not the fault of engineers, but is due to the fact that the financial loss from bad location is too distant and indirect to excite an amateur's apprehension, and every officer of a railway, from the president down, is an amateur engineer—having all the amateur's fondness for 'meddling and muddling' in *unimportant* matters, and all the amateur's reluctance to recognize anything as important which he does not himself understand. The fatuity displayed by the average railway official in this way quite passeth understanding. He will pay lavishly for his attorney's skill in trickery; he will even pay repectably for the manager's skill in dealing with men and with things; but he will neither pay for nor believe in that vastly more needed skill of the engineer, in dealing with abstract physical and mechanical laws, and in determining the financial meaning of their relationship to involved and contradictory facts. For this work he neither seeks for nor will he tolerate anything more than a hand to execute.; and the law of supply and demand gives him just what he asks for. Especially is this true in location. On the great majority of railways surveys are entrusted without the slightest uneasiness to the first graduate of the transit who comes to hand; but when he has *completed* his work, and construction is to begin, *then* we may behold an extraordinary and amusing spectacle. Then we may see half a dozen business men, who probably show some common sense in their own affairs, scouring the country with a lantern to find a constructing engineer of the greatest possible ability at the smallest possible salary—to do what? To pay over the money which is *already spent;* to pare and shave at the cost of work which might have been avoided altogether; to *build* the complicated mechanism for which they have just permitted Thomas, Richard and Henry to make designs and working drawings. This kind of folly has its root in some of the deepest foibles of human nature, and it will probably never be done with altogether; but it is to be hoped that railway companies may more generally appreciate the fact that their road is built and equipped in the brain of their locating engineer—if he has any; and that if his work be ill done, all the engineers in Christendom have done little to remedy his errors, though they execute his folly for half its proper cost. The truth is, in fact, that ordinary constructive engineering is a much lower branch of professional labor, and makes far less drafts on those qualities of mind which make the engineer. But massive piles of dirt and stone and iron are visible evidences of power which impress the imagination of the wayfaring man as equal evidences of skill, and hence it is not wonderful that the ability of engineers is more generally estimated by the grandeur of the works they have executed than by those which they have avoided."

I quote these words in their entirety, first, because they partly meet with my most hearty consent, and, second, because they are directly contrary to my views and opinions, and, third, because they contain many things which ought to be generally known and considered by everybody interested in this question. I fully agree with Mr. A. Wellington, when he says that the *location* of a railroad is the most important work relating to railroad affairs, which must be constantly and personally attended to by the chief engineer himself, and must not be left to an inferior and inexperienced "transit man." And again, I fully agree with him that the locating engineer and the constructing and building engineer ought to be one and the same person, a person who has experience not only in those two branches of railroad engineering, but also in the operating of a railroad. As Mr. Wellington has so thoroughly and admirably shown in his book, the knowledge of the financial effect of a grade or a curve is the most important in the location of a railroad; and this knowledge can only be derived from actual and personal experience; their effects can be investigated intelligently and successfully only by a man who has a thorough knowledge of the constructing of the road, and why it is so constructed, and not otherwise. The head of operation of a railroad ought to be an engineer, who is not—as he nearly invariably is, I am sorry to say—hampered in his doings by a board of directors, who profess to know everything about managing a railroad, but who, in fact, do know but how to buy and sell sugar and coffee. (That there are some brilliant exceptions in respect to these boards of directors ought not to be the cause to make them a rule). This, of course, involves a higher standard of engineers than we usually have; it involves the raising of the engineer profession to the importance it deserves, and finally must and will have. As at present the engineers are situated, it is perfectly shameful; it is inconsistent with the purpose he is here for, and is damaging to the welfare of the enterprise he is engaged for. Here is not the place to treat about this question to any extent, but it is one of vitality to the engineers.

As to Mr. Wellington's views on the contour-plan question, I have to say the following: If the system of contour maps is carried on and used as it apparently was when Mr. Wellington became acquainted with it, it certainly is a "vicious system." But, if carried out in the right way, it is certainly the most beneficial system that can be invented. To bring about such an effect, the following condition is essential: the person who makes, or personally and actually superintends, the location of a railroad, must be the same who locates the line in the contour maps; by the survey and the tramping over the ground, he requires a thorough knowledge of it, and has made himself entirely familiar with all its qualities; the contour maps, then, is for him a fully intelligible image of the ground, and as it represents a larger field to his eye than he can overlook with one sight in the field, he can judge more intelligently about the relations of distant parts to each other; he can at once decide the effect a change at any point will have on any other point. With what right Mr. Wellington says, "for the contour map is simply a device for doing ill in the office, the simplest part of the work, viz., the first approximation to the adjustment of the line in detail, and its most effectual office is to deaden the perceptive faculties of the engineer in charge of the party, and transform him into a mere machine," I cannot explain otherwise, than that he has not had much experience with the system, and that he did not get on the right side of it. The contour map is just like a relievo of the ground, and enables the engineer to work in it as the sculptor works in his clay; he can mould in it as the circumstances require it. The engineer, who has a thorough knowledge of the ground, and locates a railroad on a contour map, in comparison to the engineer who locates the railroad but in the field, where his field of view is but limited, is like the general, who leads a battle from an elevated standpoint, to the officer who has charge of only one wing of the army, being situated so that his eyes can embrace but the small space occupied by his own regiment or battalion. Now, as a change of any part of a railroad line—which is a continuous uninterrupted line—affects always some other part of it, it is necessary to investigate at once the effects the change will have on the whole line. If there is no contour map, it is necessary to locate a shorter or longer part of the line anew, which again may prove not advantageous, so necessitating a third location of this part of the road. This is the cause of great delay and expense. But when there is a contour map, such expenses can be avoided. The engineer, who is familiar with the ground, locates in his contour map the new line, calculates by means of the same map the amount of earthwork to be done, finds perhaps that this new line is not an improvement, tries another one, calculates again its cost, and so on until he finally finds the best line. And this is all done with but a slight expense. This, of course, always supposes that the contour map is a correct one, and not on too small a scale. (1.1000 or 1.500 are the most practicable scales). I will give shortly the account of a location with this system, as actually carried out by myself. I shall omit the account of the survey for the contour map, and shall suppose the latter to have been made. It was constructed in a scale of 1.500, a scale which allows the smallest unevenness, which would influence the location of railroad, to be expressed. The base line, on which the survey was founded, was approximately the future railroad line, but, of course, without curves. The first thing was to lay down the curves in the map, which were not staked out in the field, and to calculate the grade for about every 100 feet, then the so-called "intersecting curve" was constructed in the plan. This is the line, where a plane laid through the imaginary height of railroad intersects the ground; it represents to the eye at one glance approximately the points, where too much cutting or too much filling would be necessitated, hence, where the line should be changed. Where this was the case, the line was moved until it laid in about the center of the "intersecting curve," *i. e.*, so that on each side of the line about an equal part of the curve was lying. This could be found without much calculation of cross sections. When the probable best line was found, the cross sections were constructed and calculated, which were easily and quickly constructed from the map by assistants, the one reading the distances and heights from the contour map, and the other drawing the cross section on profile paper equally divided each way. The area of the sections and also the cubic content were found by means of the planimeter, the latter in this way: Draw in the center of the paper a horizontal line which shall be the axis of the ordinates, set off on it all distances of the cross sections, and erect in these points verticals; where cutting is, draw verticals above the line, and where filling, below; then set off on each of those verticals the respective area of the cross section (the areas represented by length) and connect the end points of these verticals with each other, by a continual and smooth curve; the scale for the areas, of course, may be another one than that of the distances. Then find the areas of the figures enclosed by those curves and the horizontal center line with the planimeter. These areas will be the cubic content.

These few remarks will suffice to show how useful the contour maps may be when rightly used. I shall now describe how the topographical map is made from the data derived by the tachometer. The first thing to be done is to lay down the base line, or the line which connects the different instrument points with each other, which is done by the common method of latitude and departure, or sines and cosines. The intermediate points are laid down from each point by means of a protractor, which is divided into half degrees, and has on its straight edge two scales with a common zero point, which lies in the vertical drawn through the line of 90°. The graduation of the protractor is numbered twice, once from 0° to 180°, and then from 180° to 360°. The numbers run in the direction opposite to that of the instrument. The center point of the protractor is secured by a little horn plate, with a hole in its center; this is brought over the station point and a needle put into it, so that the protractor can be turned around it as a center point. One person reads the angles and distances from the field notes (which have been completed first in regard to reduced distance and height), the other person first places the protractor so that the zero line coincides with the north line, then turns the same as much as the angle requires, and marks the distances by means of the scale and fine needle on the map. The scales of the protractor, of course, must be the scales of the map. After the point is marked down, the height, as given from the field notes, is written near it. After all points are laid down in this manner, the contour lines must be drawn, which can be done in many different ways; it should be done by the engineer, who has charge of the field party, because he is the most familiar with the ground.

According to my experience, the best and quickest way is the following: use paper which is divided into squares, with sides of one-tenth of an inch length; then draw a profile through the two points between which the contour lines shall be constructed. The intersections of the horizontal lines with this line will be the points of the contours, and their distance from the center vertical line will be their horizontal distance.

The curves must be drawn with great care and full understanding of the ground; their construction is a problem of descriptive geometry, and requires great attention.

The points, actually obtained, should not be rubbed out after the contour lines have been constructed, but they must be preserved by a little black point, and the number indicating the height also in black. The contour lines should be drawn either with burnt sienna or with green; their numbers must be written on them at many points with the same color. Each fifth or tenth curve should be drawn in a little different manner from the other—for instance, dotted or stronger; this contributes a great deal to the distinctness of the plan. All other details of the map should be marked black with the conventional topographical signs. The steepness of the ground, the scale of the map and the purpose of the work, determines in which heights the contour lines shall be drawn, whether for each foot or for each 3, 5, 10, 20 or 100 feet.

THE SLIDE RULE.

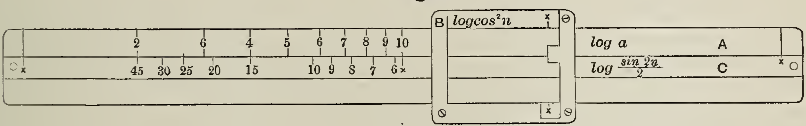
It would be very tedious and slow, to calculate for each point the respective values according to the formula, as above given for the distances and heights. There are several tables published, which, with two arguments, give the respective values, (one is calculated by Alfred Noble and W. T. Casgrain, assistants U. S. Engineer office at Milwaukee), but the best device is a slide rule, which was first constructed by the Swiss Engineer Eschman, and afterwards improved by Professor Wild in Zurich.

I suppose, the theory and use of the common slide rule is known to the reader, (if not, I refer him to my pamphlet on this subject).

The slide rule as used in topographical surveys consists of a ruler A, a slide C, and a coulisse B.

The ruler has on its upper part four equal scales, each of which is a logarithmic scale of the common numbers. The scales commence with the number one, as the logarithm of $1=0$; the space between the numbers 1 and 2 is divided into 50 parts; that between 2 and 3, and 3 and 4 and 5 into 20 parts each, and that between 5 and 6, 6 and 7, 7 and 8, 8 and

Fig. 13.



9, 9 and 10, (or 1 of the following scale) into 10 parts each; hence the scales read as follows, commencing on the left 1, 1.02, 1.04, 1.06, ... 1.98; 2. 2.05. 2.10. . . . . . 4.95; 5.00, 5.10, 5.20, 5.30, ... 9.90, 10.00. With increasing numbers the divisions become smaller, as differences between their logarithms become smaller. The values between the divisions must be estimated. The numbers indicated on the scales can stand either for the numbers themselves, or they may stand for any decimal value of them; thus, 1 stands for 1, 10, 100, 1000 etc., or 0.1, 0.01, 0.001, 0.0001 etc.; 2 stands for 2.20, 2.00, 2.000 etc., or 0.2, 0.02, 0.002 0.0002 etc. It is a matter of course, that the value given to one number of the scale influences the whole. It is practicable to give the first scales to the left, the value of from 10 to 100, and the second of from 100 to 1000.

On the coulisse B. there is the scale of log. cos. n^2 (see formula 3); this scale counts from the right to the left, as $\cos.^2 n$ is always smaller than one, the irlogirithms therefore negative? The space from

0 to 10 is equal to the log. $\cos^2 10°$,

that from

0 to 20 is equal to the log. $\cos^2 20°$,
0 to 40 is equal to the log. $\cos^2 40°$.

The first part of the space 0 to 10 stands for log. $\cos^2 4°$, the second for log. $\cos^2 6°$, and the third for log. $\cos^2 8°$. The part between 10 and 20 stand for each two degrees, and those between 20 and 40 for each degree.

This scale on coulisse B in connection with the scales on A, are used for calculating the distance, it is;

log. d=log. ($a \cos^2 n$)=log. a+log. $\cos^2 n$ log. a (the logarithm of the stadia reading) is given on scale A, log. $\cos_2 n$ on scale B.

Place the point 0 of the coulisse B above the stadia reading on the scale A, (or above the stadia reading plus 1.5 p), and look, which number in the latter scale stands below the vertical angle of scale B; this will be the horizontal distance.

Example: stadia reading $a=2.48'$, $p=12''$, $n=5°20'$; place 0 of scale B above 249.6 ($a\,k+c$) of scale A, and read under 5° 20′ the reduced distance estimated to 248′; if the angle were

10°, D would be $=242'$,
20°, D " $=221'$,
30°, D " $=187.7'$,
40°, D " $=146.4'$, etc.

From this instance, it can be seen that for smaller angles the result, as given by the slide rule, is not as exact as for greater angles, but still exact enough for practical purposes.

On the slide C there is the scale of $\log \frac{\sin^2 n}{2}$ [see formula (5)]. It commences with the value for 35 minutes at the right hand end, and the graduations from 1 to 3 stands for each two minutes,

3—5	"	"	5	"
5—10	"	"	10	"
10—20	"	"	20	"
20—30	"	"	30	"
30—40	"	"	1°	"

from 40°—45° there are no smaller subdivisions.

Formula (5) is

$$\log Q = \log ak + \log \frac{\sin 2n}{2};$$

therefore, place the line for the vertical angle on the scale C under the stadia reading of scale A_3 or A_4 and find above the left index (the line with the star) the height. In the case the left index falls beyond the scale, the center index or the right one can be used, but it must be considered that the center one gives ten times, and the right one hundred times the reading of the left index.

For the number of places of the height, we have the following rule: If the height be found in the same scale as the distance (or the value ak) is taken and the left index be used, the height has as many places as the distance; but if, in the same case the right index be used, it has two places less than the distance, and if the center index is used it has one place less than the distance; if the height be found in the proceeding scale and with the left index, it has one place less, and if in the same case the center index be used it has two places less, and if the height be found in the following scale with the right index, it has one place less, and if with the centre index it has just as much as the distance. In the following table z stands for the number of places of (ak):

Scale in which height is found.	Which index used.	Number of places of height.	$a\ k$	n	Q.
Same as distance............	left	z	400	18°	118. 8′
" "	center	z—1	2400	5°	208. 0′
" "	right	z—2	2400	37′ 48″	26.16′
Proceeding....................	left	z—1	900	54′	14.06′
"	center	z—2	1750	2° 42′	82. 5′
Following....................	center	z	34.7	27°	14.05′
"	right	z—1	9	54′	0.141′

For smaller angles than 35 minutes the angle must be multiplied (perhaps by 10), and the result divided by the same number, which safely can be done, as for small angles the sine is nearly equal to the arc. If we had, for instance, $n=0°6'$, we would take $6\times10=60'$ or 1°, and place this angle below the stadia reading and divide then the result by 10. Example: $a=3.45$, $n=20'$; place the angle $10+20'=3°20'$ below 345, find

$$Q=\frac{20.00}{10}=2.00$$

(the exact result is 2.05).

On the lower edge of the slide rule, there is yet another scale, which is used for the reduction on account of refraction and curvature of the earth in greatly extended topographical surveys. For this scale, the lowest index, which corresponds with the others, is to be used in this way: Place the index of the coulisse B over the distance in scale A and find the correction under the lowest index on the scale of the lower index. These corrections are in the metric system. For instance:

$D=500^m$, Correction $=0.017^m$,
$D=1000^m$, " $=0.068^m$,
$D=1500^m$, " $=0.16^m$,
$D=2000^m$, " $=0.26^m$,

etc., which correction is to be subtracted from heights.

PNEUMATIC FOUNDATIONS.

Description of an Improved Closing Port, for the Discharge in Lock.

By A. HEINERCHEIDT.

Translated from "Annales des Ponts et Chaussées" for Van Nostrand's Magazine.

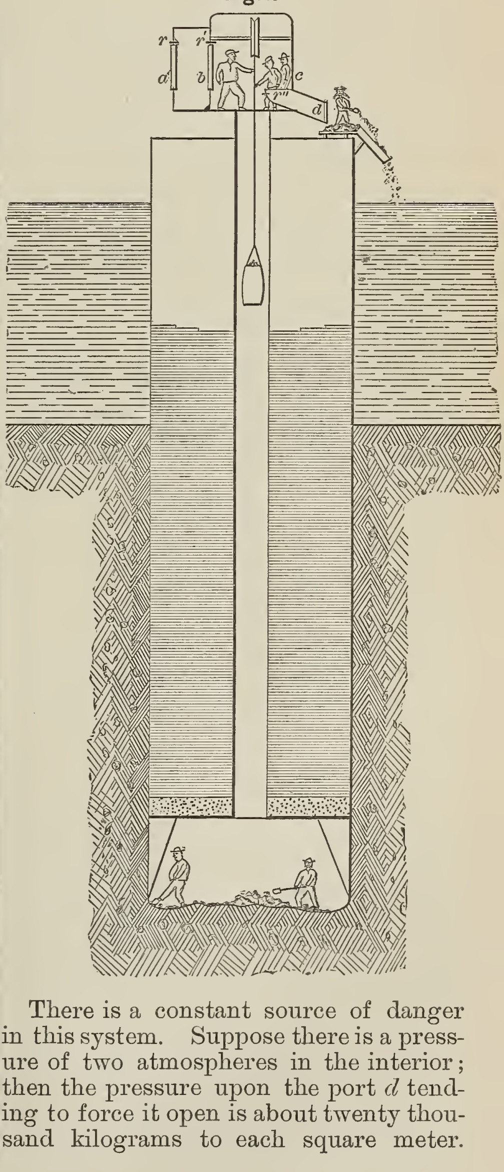
Foundations for abutments or piers which are constructed by aid of compressed air, generally employ a cylindrical caisson of iron, divided into two unequal parts by a horizontal partition; the upper part, which is the larger, is the caisson proper. It is a coffer dam, within which the masonry is built in the open air. The lower part, which is filled with compressed air, and within which the excavation is carried on, is called the *working chamber*. It is furnished with one or two shafts made of boiler iron, which are surmounted with an iron chamber called the air chamber. Adjoining this is the "equilibrium" chamber, or air lock, through which workmen and materials must enter. A pipe from the compressing engine furnishes the air chamber with compressed air. The air chamber and air lock are generally located above the highest level of the water, in order to insure the escape of workmen in case of accident to the dams above.

Figure 1 exhibits the relative position of the various parts.

The outlets to the air chambers—the air lock and the chutes—are furnished with two ports to be opened sucessively. The ports *a* and *b* of the air lock open towards the interior, so that the air pressure tends to keep them closed. To open either of them, it is necessary to equalize the pressure upon its opposite sides by means of the cocks *r* or *r′*. There is thus no danger of the port opening suddenly.

On the other hand the *discharge lock* is furnished with a port *d*, which of necessity opens outwards. Normally the port *c* is open, and the chute or lock is charged from within. When it is filled, the port *c* is closed, and a workman on the outside in charge of the port *d* is notified by a convenient signal. The outer port is then opened, and the charge removed. Then follows the closing of *d* and the opening of a cock *r″* which puts the discharge lock in communication with the air chamber. Equilibrium being thus established between the two sides of the port *c* it is reopened, and the charging is again resumed.

Fig. I.



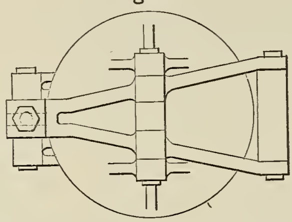
There is a constant source of danger in this system. Suppose there is a pressure of two atmospheres in the interior; then the pressure upon the port *d* tending to force it open is about twenty thousand kilograms to each square meter.

Any mistake on the part of the workman who has charge of the exterior port, whereby *d* is opened while *c* is also open would result in serious disaster to the workmen within.

In order to prevent such a catastrophe the following plan has been devised by the writer. It is designed to prevent absolutely, the opening of the exterior port until the interior one is completely closed.

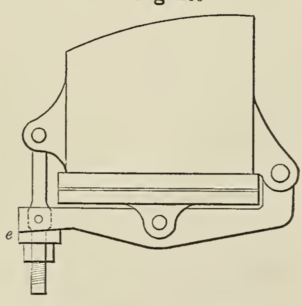
Fig. 2 represents the exterior port *d*.

Fig. 2.*a*



It is a cast iron disk suspended at the middle upon a shaft, which latter also is made to pass through two iron ribs, which cross the disk to unite in a fork at one edge, and diverging from this point terminate on the other side of the disk in a hinge point, working about an arbor fixed to the side of the chute. A third arbor also attached to the chute on the

Fig. 2.*b*



opposite side supports a rod, which passes through the forked rib, and is secured by nut and washer as shown in Fig. 2. When this screw is tightened, an equal pressure is exerted on the entire circumference of the seat of the disk. By employing rubber, an air tight joint is secured.

Thus far the description applies to the system in general. The modifications introduced by the writer are as follows:

The fork which receives the screw rod is constructed with a sloped bearing for the washer, as shown at *e*; the washer being also made to fit its seat. This secures the port against being thrown open from any pressure from within; also against too sudden opening by ordinary means. Several turns of the nut are required to allow a very small opening of the port. The workman, therefore, employs less force, and is relieved from some of the precautions employed before. A hole is made through both branches of the fork, and through the screw rod. Through this hole is passed a vertical rod, to the upper end of which is attached a bent lever. To the other arm of the bent lever is connected a horizontal rod. This latter passes through stuffing boxes into the air chamber, so as to be controlled from within. (Fig. 3.)

The working is easily understood. When the outer is closed, it is necessary before opening it to raise the vertical rod. This cannot be done unless the inner part is entirely closed.

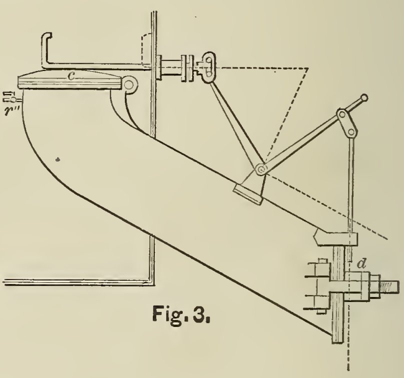


Fig. 3.

This device has been lately employed upon two air locks at Boom, for sinking pneumatic foundations for a bridge over the Rupel.

Two different plans were employed by reason of the different situations of the chutes in the two locks, but the principle is the same in both. The entire apparatus is light, not cumbrous; the time of working it is only the time required to raise the hand, and the security is absolute, as the reader is probably convinced by the above explanation.

The apparatus has been in use for two months, to the entire satisfaction of employees, and especially of workmen employed within the air chamber.

THE ACOUSTICAL IMPROVEMENT OF LARGE HALLS.

From "Engineering."

It is of course well known that the proportions of a room, as well as the character of the surface and contour of its walls and ceiling, exercise an all-important influence on its acoustical properties, and that even when every care has been taken in the designing of a concert hall or opera house to proportion the relative dimensions of its parts, as far as present knowledge of the subject can suggest, so as to obtain good acoustical results, it too often follows that the desired end remains to a great extent a matter of chance, and it is a curious fact that two buildings built upon the same model, and of identical proportions, often have totally different acoustical properties, and that a building may have its acoustics altogether altered for better or for worse, as the case may be, by the addition of decoration in the form of mouldings, cornices, curtains, and banners, and it has recently been pointed out by Dr. C. W. Siemens, F.R.S., that even the lighting of the gas in large buildings, such as the Albert Hall, by producing laminæ of heated air, can materially affect the acoustic conditions of the structure. It is obvious, therefore, that any contrivance which would enable the designer of a building intended for music or for public speaking, to insure against acoustical defects in his structure, or which would improve its capacity for the distribution of sound in the auditorium, would prove of the highest value to engineers, architects, builders, and contractors, as well as by all interested in the building, renting, or using of such places of public resort, and there have from time to time appeared schemes of one sort or another having the attainment of those very desirable objects in view.

The acoustic defects of large buildings are brought about by one or more of the following acoustic phenomena, and in some cases by all combined. (1) Dispersion, by which in large and lofty buildings, such as many of the magnificent Gothic cathedrals, the greater part of the sound waves produced by the human voice are free to wander away through great distances, until they expend themselves among the arches and galleries of the roof, and in the cavernous recesses of the chapels and transepts, leaving but a small proportion to reach the ears of the people in the body of the hall. (2) Resonance, by which discordant reverberations are produced, commencing nearly simultaneously with the note or sound by which they were originally induced, but continuing for some time after the original sound has ceased, and, therefore, interfering with the notes that follow. This is a common defect of domed and vaulted buildings, and the phenomenon may be observed in empty houses, and very often in tunnels in which it is combined with reflection or echo, with which it must not be confounded, although the two are seldom, if ever, found apart. Resonance is chiefly attributable to the sympathetic vibration of the air held within the vaults of the roof, or within a dome or gallery set up whenever a note is sounded whose period of vibration corresponds with that of the space in which the resonance is produced. But what is perhaps the most serious cause of defect in moderate-sized buildings is (3) the acoustical phenomenon of reflection or echo. It is by acoustical reflection that the sound waves traveling away from the speaker in all directions are arrested in their course by walls, ceilings, arches, and other reflecting surfaces, and are thereby prevented from exhausting themselves in space by being turned back in directions determined by the nature of the reflecting surfaces, and their positions with regard to the original source of sound; and were it not for the comparatively slow speed with which sonorous vibrations travel, reflecting surfaces would improve and intensify the original sound in both large and small buildings, much in the same way as a number of mirrors in a room improves its illumination by reflecting back a large proportion of the light which would otherwise be dispersed or absorbed.

It is generally considered that the quickest speed of talking which can be articulated clearly and heard distinctly, is five syllables per second, and and as the velocity of sound is only 1125 ft. per second, it follows that in the time which elapses in quick talking between the articulation of one syllable and that of the next, the same sound could travel 225 ft., so that if a reflecting surface be 112½ ft., distant the reflection or echo of the first syllable should be heard at the moment the second syllable was being articulated, and would therefore clash with it as would the second with the third, and so on, and if there were other reflecting surfaces at distances two, three, and four times the distance of the first, their reflections or echoes would interfere with the second, third, and fourth syllable respectively from the first spoken syllable, and this clashing or interference of sounds, so destructive to the audibility of a speaker, is almost more serious for a singer, as notes are introduced at the wrong time, giving rise to discords and false combinations, and producing what has been called a "wooliness of outline" to the music which is being performed. Reflecting surfaces in close proximity to the source of sound improve and strengthen it as a reflector behind a source of light intensifies its front beams; it is only when the distance of the reflecting surface from the source of sound is such that the time occupied by a sound wave in traversing that distance and returning again occupies, say, the fifth of a second of time or more, that the reflection becomes an echo and is injurious to the acoustical properties of the building. In fact the difference between what is called a useful reflection and an injurious echo is merely one of distance. The common sounding board above a pulpit—which in this country is too often a disfigurement and an outrage upon architectural taste, and in Belgium and some other Continental cathedrals is made an exquisite piece of æsthetic ornament—is an instance of the use of a rereflecting surface close to the source of sound not only for directing the sound waves on the audience, but for shielding them from two of the evils to which we have just alluded, namely, dispersion and echo. If sounding boards of the same angular dimensions with respect to the speaker were placed at distances from him greater than 112 ft. they would do nothing but harm, injuring by so many more sources of echo the acoustics of the structure in which they were fixed. Closely allied to and associated with the phenomena of reflection and echo is that of (4) interference, whereby sound waves are neutralized or intensified, according as the return or reflected waves meet others advancing in such a manner as to destroy or to coincide with them respectively; in other words, if they meet crest to trough or crest to crest, the former producing more or less a silencing of the sound and the latter an augmentation of it; and as these silencings and augmentations, from the very varied wave lengths of the sounds constituting either musical compositions or articulate speech, are altogether promiscuous in their occurence, it follows that audition is, by the phenomenon of interference, confused to a very serious extent. There is one more source of acoustical defect in large rooms, and that is (5) sympathetic vibration of sonorous bodies within it; this phenomenon is closely related to that of resonance mentioned above, but it differs from it in the manner in which it is produced. It is well known that a piano or a harp placed in a room in which a concert is being performed, although not being played upon, gives out a large proportion of the music being performed, and a person sitting near it can hear the music coming from it, as if some ethereal hand were playing upon it with the lightest possible touch. This very interesting effect is nothing more than the taking up by each string the vibrations of the air surrounding it which were thrown into tremor by notes emitted by other instruments whose period bore a harmonious relation to that of the string so affected. But it is not only strings that are so influenced—metal plates of various sizes and thicknesses, membranes such as a drumhead or a tambourine all are influenced by sympathetic vibration, and give out corresponding notes. It must be familiar to many persons that even a common hat held in the hand in the presence of loud music is thrown into a state of vibration when certain notes are sounded, which vibration is distinctly sensible as a tremor to the hand holding it, and we may say generally that anything capable of being thrown into vibration with sufficient rapidity to constitute a sound may be thrown into sympathetic vibration by corresponding sounds produced with sufficient force in their neighborhood.

We think we may safely say that all the above phenomena, with the exception perhaps of the first, *i.e.*, dispersion are with respect to their acoustic influence upon a building either decidedly useful, harmless, or positively detrimental, according as the distance of the disturbing body from the source of sound be small or great. Thus the cavity of the human mouth, as well as the important parts of most musical instruments, are resonators, which not only greatly improve the sound, but to which their quality, value, and character are chiefly due. Again, reflectors, such as pulpit sounding-boards and walls in close proximity to the speaker or singer, augment and intensify the effect as a mirror augments a light, and to the resonance and sympathetic vibration of solid bodies is due the reinforcement and enrichment of sound produced by instrumental sounding boards, such as that of a pianoforte, or those of other stringed instruments, such as the violin, violoncello, and double bass, and of which no more striking illustration can be given than the familiar one of placing the stem of a vibrating tuning-fork against a resonating body, such as a table or hollow wooden box.

Mr. Engert's invention is the utilization of the phenomenon of the sympathetic vibration of metallic plates placed in the neighborhood of the performers for taking up the notes as they are sounded, and giving them out again so as to mingle their synchronous sound-waves with those produced by the original notes, and thus to intensify them and give them more body. With this object he places behind and about the platform a number of sets of sheets of steel of various thicknesses and areas, suspended to framework and attached to one another by spiral springs, so that they are free to move within certain limits in every direction, and being of very different thicknesses and size, each plate can pick out, as it were, its own set of notes which it reinforces, and those notes by which any particular plate is uninfluenced are taken up by other and different sized plates, whose periods of vibration correspond to a different set of sounds. At a trial concert, recently, Mr. Engert had placed behind the performers five sets of suspended steel plates, one set being at the back center of the platform, and the others being in two pairs, one on each side of the center, the whole being arranged more or less in an arc of a circle embracing the platform; and in front of the platform in the middle were three smaller sets of plates, behind which and close to them was placed the pianoforte. Each set consisted of five steel plates of different sizes, suspended in a vertical position parallel to one another, about an inch apart, by spiral springs, and having a second set of spiral springs which acted as distance pieces between them. The five sets at the back of the platform were enclosed in flat vertical cases, the fronts of which consisted of a set of louvre boards, which could all be opened or shut together exactly like the opening or closing apparatus of the swell of an organ, and by closing any one set of louvres that particular set of plates could, for experimental purposes, be thrown out of use, and with a similar object the smaller sets in the front of the platform were provided with curtains which could all be simultaneously drawn aside or closed up by means of strings.

During the performance of the concert there was unfortunately but one opportunity of testing the effect of the music, first with the apparatus in use, and then with the louvres and curtains closed up, and this was afforded by one of Signor Foli's songs being "encored" and repeated, the apparatus being in use during the first performance, but shut off during the repetition. That there was a difference between the two, no one with any pretence to a discriminating ear could be insensible, but we venture to think that the question whether the one was an improvement on the other or not was a matter purely of imagination, and from the opinions of others with whom we compared notes, we think that if a poll had been called of the impressions of those present as to whether the apparatus improved the effect or not the ayes would have been about equal to the noes. It is only fair, however, to state that it was announced by the inventor that the apparatus was far from being in good order, and in fact that some of the suspension wires had been broken altogether through not being of sufficient strength to support the weight of the plates. We must confess that we do not see the applicability on any extended scale of such a system to the improvement of large halls, for the reason cited above, namely, that sympathetic vibrations, reflections, and resonances in order to be of any use for the improvement of sound must be close to its source, and therefore the amount of apparatus for the production of such phenomena must be very limited, and can in large buildings bear but an insignificant proportion to the size of the chamber, and to the many sources of defect which vastness of size introduces. We can readily believe that if the velocity of sound were equal to that of light, the multiplication of sets of Mr. Engert's vibrating plates placed all over and above the interior of a building, in the roof and around the galleries, might greatly augment and perhaps improve the sound, but as it takes a decidedly appreciable time for a sound to travel a distance which can lie within a moderately sized concert hall, we cannot but think that every set of apparatus placed within the building, except in the immediate vicinity of the platform, would add to the discordant reverberation, add to the echoes produced, and would in short be a remedy far worse than the disease it is intended to cure. Passing from general principles to matters of detail, we fail to see the advantage of mounting the plates upon springs; if we understand the phenomena correctly we are under the impression that the sort of vibration of the plates which is desired is a mebranous one, and not a bodily swing of the whole plate as a mass, which could hardly be rapid enough, or be in a condition to be imparted to the air so as to reproduce a musical note, and if this view of the case be the correct one, the plates might be rigidly fixed by their upper edges, or even all round, like the head of a drum, and their membranous vibration would not thereby be destroyed, but rather improved.

We are the more sorry to take this view of Mr. Engert's invention (to which the name Orpheophone might not be inaptly applied) from the fact that we understand it is the result of an experimental research extending over more than forty years; it may be, however, that we have not properly appreciated the reasoning by which he was led to his conclusions, or by which he anticipates being able by his invention to impart the most admirable acoustical properties to buildings of the worst acoustical construction. If we have misunderstood him we shall be only too glad to rectify the error by affording him an opportunity for the explanation of his undoubtedly ingenious apparatus.

THE FUTURE OF PORTLAND CEMENT

From "The Building News."

The manufacture of Portland Cement is at the present time passing through a crisis in its history. The inventions of Messrs. Goreham, Johnson and Michele have rendered unnecessary nearly half the plant formerly required, and works of the type in common use only a few years back will soon have become obsolete. Thus by the use of a minimum quantity of water and the employment of mill-stones for reducing the mixture of chalk and clay to a fine state of subdivision, as specified by Mr. Goreham, the "backs," covering a large area of ground, can be wholly done away with; and the mode of employing tunnels or chambers attached to the kilns, patented by Mr. I. C. Johnson, obviates entirely the necessity for coke-ovens, drying-floors, and some of the most costly and troublesome of the processes which have until recently been considered indispensable to the manufacture.

Nor is it merely in the processes used in the production of the cement that important changes are impending; the whole system of testing the cement will be likely, sooner or later, to be modified, and already in Germany it has been decided to abandon the present unsatisfactory plan of testing the neat cement, and to introduce one standard system throughout the entire country—of employing for this purpose test-briquettes made from a mixture of cement and sand. One important fact, which must not be lost sight of, is the great reduction in price which has been already established by the simplifications introduced into the manufacture.

At the present time there can be but little doubt that in London it would be almost as cheap to use Portland cement mortar as to employ that made from the grey chalk limes now in almost general use in the Metropolitan district. It would be extremely difficult to persuade architects, engineers, and builders that such is the case; and we shall perhaps be thought rather over-sanguine in making such an assertion; but we are convinced that the time is rapidly approaching when Portland-cement mixtures will drive common lime mortar out of the field. Let us glance at the relative prices of cement and lime mortar, assuming that the cost of mixing them per yard of sand is the same in each case, and taking it at 2s., though in reality it is far more difficult to slake, and thoroughly mix lump-lime and sand than to make a mortar from Portland cement. 1st. As concerns prices: Portland cement is sold by the manufacturer by the ton of 2,240 lbs. The retailer, for the purposes of the London trade, puts up ten sacks each of 200 lbs. net, and sends out 20 "centals" of 100 lbs. each as a ton of cement, looking upon the remaining 240 lbs. as part of his profit.

Our advice, therefore, to large consumers, is to buy by the ton, not by the ten sacks.

The manufacturer, however good and perfect he may make his cement, finds that at the present prices it does not pay him to sell all his cement in what we term a "potential" condition; neither do any of the existing tests necessitate that he should do so; he, therefore, sends out a mixture of from 80 to 90 per cent. of Portland cement, and from 10 to 20 per cent. of "core," or hard particles, which certainly have no beneficial action, and may even be productive of serious injury to the consumer. If, as manufacturers assert, the present competition in the cement trade renders unavoidable this slovenly mode of grinding, or rather this neglect of sifting, it would be far preferable to permit Portland cement makers to add, to sifted cement, from 10 to 15 per cent. of fine grained sand, pulverized quartz, or slag, and to sell such a mixture as "adulterated cement."

By a strange anomaly, writers upon the subject, and even some experimenters, have made use of the argument that because, under certain conditions, a heavy cement (with 15 per cent. of residue, when passed through a sieve of 1,600 meshes to the square inch) will give better results when *tested neat*, if this residue is left in, than if only the fine particles are tested, therefore there is no object in the removal of the core; forgetting entirely that in practice such cement is not *used neat*, and that under a sand-test, with two or three parts of sand, this apparent advantage in the presence of the coarse particles at once vanishes. Another very singular fact is that in nearly all sieve-tests which have hitherto been suggested, a minimum residue with a certain sized mesh is propounded. Now if there is to be any good in the sieve test at all, and we hold this to be the most important of all tests with Portland cement, the entire absence of core with a sieve of a certain named number of meshes must be insisted upon. The sieve test should read: "The whole of the cement must be so ground as to pass through a sieve containing $40 \times 40 = 1,600$ meshes to the square inch, without any residue." It is curious how wrongly manufacturers regard this question of sifting. We were talking quite recently with a prominent cement maker on this subject, and he said: "If my cement had to be reduced to such a pitch of fineness, I should have to give up the business, as I should never get through the grinding." We asked him if he could give us even the roughest estimate of what ths extra cost might be, and he replied, "Half as much again as at present." On checking some of the cement as it ran from the hopper of the millstone, with a sieve of the size named, there was found to be a residue of $12\frac{1}{2}$ per cent. of core. When we pointed out that the total extra cost could not possibly exceed the expense of re-grinding this percentage of his present output, plus the cost of sifting, and raising the core back again into the stones—the expense of the two latter operations being admitted to be almost inappreciable, he said he had never considered it in this light, but had thought of the power and labor necessary to grind *all his cement* fine enough to go through such a mesh at a single operation!

This is rather a long digression from the subject of the cost of cement; but it has been necessary, in order to prove that nearly all the cement in the market is degraded to the extent of nearly 20 per cent. by inert and unprofitable ingredients. As a forcible illustration of this, we once pointed out to an engineer who had been sending 10,000 tons of Portland cement to some large works in Russia, and who told us that the cost of transport exactly doubled the prime cost of the cement: "You have expended about £3,000 out of the £20,000 in sending grit to Russia, and this you might have saved by having all the cement sifted in this country before it was put into casks."

The cost of Portland cement, bought by the ton, and specified as capable of undergoing the usual tests, was, for a large work on the South Coast, recently quoted at 31s. 9d. This would imply a price in the London district of about 30s. per ton of 20 bushels at 112lbs. each, or, say, 31s. 6d. per cubic yard of 21 bushels. Taking sand at 4s. per cube yard, and a mixture of 5 yards of sand to 1 yard of cement, which, with sifted cement, gives a very excellent mortar; we get for 31s. 6d. + 20s. + 10s. for mixing, 5½ yards of cement mortar at a cost of 11s per cubic yard.

Gray lime is still sold in London, to the great advantage of the dealer, by the cubic yard, which is a survival of the obsolete "hundred," as we pointed out in a former article; but, without attempting to show what is obtained for a yard, we will ask our readers to assume that a cubic yard of gray lime, containing 21 imperial bushels, which we require for comparison with Portland, may be supplied for 10s. With this quantity, whatever specifications may have to say upon the subject, we have found, from careful observation, that the "intelligent Irishman" who makes the mortar uses two yards of river sand, or 2½ yards of pit sand (say the latter, to make out as good a case for lime as possible), and he obtains only, at best, 2½ yards of lime mortar for 10s. + 10s., and 5s. for mixing, or 10s. per cube yard, as against 11s. for Portland cement mortar. The former being a very poor and miserable imitation of the result obtained from the use of cement, which we trust soon to see taking its proper place as a London building material. It is true that this calculation implies an actual cubic yard of *pure* Portland cement, and one of freshly-burned lump lime, and both at prices rather below those to which we are accustomed. It is also true that lime could be sold much cheaper, and that Portland cement has perhaps been forced down to its lowest paying price. Still, with a difference of only 10 per cent, in the cost of the mortar, there should be no hesitation in the choice of which to use. The reduction in the cost of making Portland by the modern process, in the one item of fuel alone, shows a saving of 50 per cent.; the amount of coke used being stated for all purposes at from 8 cwt. to 10 cwt. per ton of finished cement.

We wish to say a few words, in conclusion, on the German system of testing a sand mixture in lieu of the neat cement. As we have stated on previous occasions, the existing plan of insisting on a cement of a given weight per imperial bushel is, when unchecked by the sieve, a direct incentive to imperfect grinding; as it is far easier to prepare a cement with 20 per cent. of coarse particles, weighing 118 lbs. per bushel, than one much more finely ground and deprived of its coarse particles, which would weigh only 110 lbs. Many engineers have been accustomed to regard cements ranging from 112 lbs. to 120 lbs. per bushel as superior to those weighing under 112 lbs.; it is, however, impossible to form any opinion on this point unless the fineness of the particles had been ascertained. The experiments of Mr. Colson bearing on this subject, published in the *Transactions* of the Institution of Civil Engineers, are of the utmost value. Theoretically speaking, we believe that there is no good object gained in aiming at a cement of over 110 lbs. to the bushel. Indeed we doubt if any cement deprived of its core by passing it through a 40×40 mesh sieve could be made to surpass this weight.

A great impediment to the sand test is

the fancied difficulty of obtaining a sand of uniform quality. A pure quartz, crushed to a powder which shall consist of grains rejected by a sieve, say, of 2,500 meshes to the square inch, but deprived of all grains too large to pass through a sieve containing 900 meshes, could be procured all over the country, and would surely be sufficiently uniform for the purpose. The section for fracture which had been selected in Germany of only 5 square centimeters, certainly appears small for the briquette; but we must remember that the smallest sectional area capable of giving reliable results is the one which will expose us to the smallest margin of error, due to imperfection in filling the mould, and gauging the compound of cement and sand. Whenever the sand test becomes adopted by English cement users, we expect to see the area of $1\frac{1}{2}$ inch by $1\frac{1}{2}$ inch selected, in preference to the standard area of 0.78 square inch chosen in Germany.

The last and perhaps the chief objection to the German sand test is the twenty-eight-day period, which must intervene between the testing and use of the cement. We are not yet quite certain that an interval of more than fourteen days is necessary, and by adopting this limit, with two instead of three parts of sand to one of cement, we think the chief argument against the sand test would disappear. It is a matter which no longer admits of any doubt, that for many of the dense cements now in such high favor with our English engineers, the seven-day test does not permit of a sufficient amount of induration to show the action of the cement at its best, as compared with a lighter cement tested in a similar way. The sand test, strangely enough brings out the high quality of a cement much more effectually than the mode of testing now in use, and admits of far more uniformity in the results.

It is a pity that no central body exists in this country, capable of uniting all the principal men interested in the employment of Portland cement, either as architects, engineers, builders, or manufacturers. Failing such a central authority, a joint meeting of the Royal Institute of British Architects and the Institution of Civil Engineers might be convened to report on this matter, as was done in Germany, and to decide upon some uniform plan of testing. We see no reason why this should not be accomplished, to the great benefit of all English users of Portland cement.

A FEAT IN TRIANGULATION.

From "Nature."

A NOTEWORTHY advance in geodesy has recently been accomplished by the junction of the network of measurements covering a large portion of the surface of Europe, with the African continent. The entire triangulation of Algeria was completed by French engineers some time since, and extended to the edge of the Sahara, in lat. 37°. M. Perrier, who had directed in a great measure the triangulation of Algeria, has for the past eleven years been seeking the means of joining the network in that country with the perfect trigonometric system covering the surface of Spain, France, and England. The importance of such a junction is easily appreciated when we consider what notable changes in the accurate conception of the shape of the earth and of the length of meridians has been effected by measurements on a much smaller scale.

For such an undertaking the most careful and painstaking preparations were requisite. As the result of his reconnaissances between 1868 and 1872, M. Perrier found that from all the trigonometric points of the first order between Oran and the frontiers of Morocco, the loftier crests of the Sierra Nevada on the Spanish coast opposite, were visible in exceptionally clear weather. Arrangements were subsequently made with the Spanish Geographical Institute for the mutual and contemporaneous execution of the proposed plan. A corps of Spanish officers, under the direction of the well-known General Ibanez, was detailed for this purpose, while the French Minister of War placed a division of officers from the *Etat-Major* under the command of M. Perrier. The leaders chose for stations in Algeria the summits of Mount Filhaoursen and Mount M'Sabiha, west of Oran, and in Spain the summits of Mount Tetica and Mount Mulhacen, the latter of which is the most elevated point in the kingdom. The directions and distances between these four points were computed as carefully as possible, and preparations were then made for the final and determinative observations. At the Algerian stations the nature of the country and its inhabitants necessitated the use of a numerous force of soldiery as well as of means of transport.

In order to insure the accuracy of the observations, which required the passage of signals over a distance of 270 kilometers, it was decided to make use of solar reflectors and powerful lenses. The efficacy of such apparatus for even greater distances had already been tested by M. Perrier; still for the measurements in question they appear to have utterly failed to answer the expectations based upon them, not a single solar signal being visible from any station. Fortunately, the success of the observations did not rest entirely upon this one system of signals. Preparations had likewise been made for the employment of the electric light, and on the summit of each mountain one of Gramme's electro-magnetic-machines worked by engines of six-horse power had been placed into position.

On August 20 last, all the stations were occupied, and the electric lights were displayed throughout each night. Then the patience of the observers was submitted to a lengthy proof. The mists rising from the Mediterranean totally prevented the exchange of signals, until after a delay of twenty days, one after another the electric lights became visible even to the naked eye. Perrier compared the intensity of the light on Tetica nearly 270 kilometers distant, to that of a in Ursa Major, which rose near by. The observations were continued from September 9 to October 18, when this task for which such extensive preparations had been made, was completed in the most satisfactory manner. With its completion we come into possession of trigonometric measurements of the most exact nature, extending from lat. 61° in the Shetland Islands, to lat. 34° on the southern frontier of Algeria.

The extension of this network southward and eastward in Africa, desirable as it is for the elucidation of many nice points in geodesy, is unfortunately scarcely possible in the immediate future, and science must rest content with gaining a foothold in the great continent.

A Hugh Gasholder.—Messrs. Ashmore & While, of Stockton-on-Tees, have just secured a contract for the erection of what will be the largest gasholder in the world. It has been designed by Mr. George Livesey, for the South Metropolitan Gas Company. It is of the kind known as treble lift. The inner vessel is 208 feet diameter by 53 feet 6 inches deep in the sides; the middle vessel is 211 feet diameter by 53 feet 3 inches deep; and the outer vessel 214 feet diameter by 53 feet deep. It will thus be seen that when full, the top curb of this holder will be approximately 160 feet high above the tank water-line. The cubic capacity of the vessel will be 5,000,000 feet, The holder when at work will be retained in its position by means of twenty-four wrought iron stanchions, constructed of plates, bar, and angle iron, tapering from 28 feet wide at the base to 22 feet at the top, and 165 feet high, or thereabouts. These are connected laterally by a series of strong horizontal struts or girders of + section, and by diagonal braces of flat iron, increasing in strength from the top downwards. The tank containing this enormous vessel, and supporting the framing referred to, is in course of construction in concrete upon the special plan designed also by Mr. Livesey. What a contrast we have here between modern gas engineering and the time, within the memory of many men, when a London gas company kept a few thousand feet stored in balloons for their customers; while the Chartered Gas Company was once so hard up for a gasholder, that it purchased a second-hand brewers' vat and used it for the purpose.—*The Engineer.*

RAILROAD SHAKES.

By S. W. ROBINSON, Department of Physical and Mechanical Engineers, Ohio State University.

Written for VAN NOSTRAND'S MAGAZINE.

THIS term may perhaps justly be applied to a sort of railroad malady, which so afflicts some roads that passengers riding over them are sure to suffer in consequence, without respect of person; and the remedy is not to be found in bolus or pellet. Indeed to become seasick on a railway train is of somewhat frequent occurrence, so severe are the storms of *railway shakes.*

When an engineer stakes out a railroad, great care is exercised in the "alignment"; and the rails must be adjusted with nicety to it. Deviations would look bad, and quite small ones could be detected by the eye alone. It is therefore quite essential that this be carefully attended to, though another alignment of even greater influence upon the train, but whose error is less easily detected by the unaided eye, is almost entirely ignored; and at best left to the mercy of the section men.

A person standing upon a straight railway track could, by sighting, detect an error of $\frac{1}{4}$ inch to the 100 ft. in straightness. Deviations vertically could be about as easily detected if the eye were to take a favorable position for examination. But the fact that nobody is likely to take the trouble to thus inspect the track is, it seems, taken as license for admitting errors to the extent of an inch or more to the 100 ft. There is many a track which, if the horizontal and vertical alignments were interchanged, would become astonishing objects to behold. No railroad man would approve such a track, and yet the effect of it, in shaking up a train, would be far less than before the interchange. A few considerations will suffice to indicate this.

First—Suppose a car to follow a track full of such horizontal inequalities, the vertical errors being nil: The whole car would be jogged about to the same extent; the top as much as the bottom. But the cars would probably not follow the track exactly, some of the short turns being dodged over, and to this extent the jostling would be modified. This would be still further relieved in trains where the couplers form comparatively rigid connectors, as adopted now on many roads.

For the sake of the comparison, suppose next, that the track errors are as usual, viz: vertical. Now first, if both rails rise and fall exactly alike or together, the car would rise and fall to the same extent; these displacements being the same as the lateral movements in the previous case, if the car followed the rails exactly. But because gravity compels the car to follow the vertical crooks exactly, and as it would hardly follow the horizontal ones, the passengers would suffer most from the errors in vertical. But in the second place the two tracks will not exactly duplicate each other's crookedness, one rail perhaps being lowest where the other is highest. Such a condition of track will of course greatly aggravate the jostling action; the car being tilted first to one side and then to the other. To get a little idea of this, suppose one rail to be exactly straight, and the other in error vertically. Then, at the point of a depression, for instance, of one inch, the tilt or rock of the car, with the straight rail the axis of motion will be one inch at every point in the arc of a circle, or rather surface of a cylinder struck through the car, about the straight rail as center or axis, the radius being the gauge of track. If the latter distance be $4' \, 8\frac{1}{2}''$, the passengers will be beyond this circle, and hence their displacement will be greater in extent than the $1''$ error in the one rail. Now if the two rails are in error, the possible disturbance will be about doubled, the effect of which is anything but pleasant.

Section foremen, who largely control this matter, should therefore be selected with care as possessing the skill necessary for securing the desired adjustment of track.

In the preceding, the terms horizontal and vertical, as applied to alignment, are used in the same sense as when applied by engineers to curves, as horizontal or vertical curves. Horizontal alignment has reference to the line, as projected upon a horizontal plane, etc.

Perhaps too little credit is given in the above to the civil engineer, for the relative portions of attention devoted to the two kinds of alignment. The leveling instrument is one whose precision falls not very far short of that of the transit, and hence the center line, as given to the construction masters, may be faultless in every respect. But as this line consists of points only, and 100 feet apart, or possibly in some cases, less, it follows that the intermediate points may, without any wit or allowance of the engineer, be subject to considerable deviations, especially as this is mostly left in great measure to no better instrument than the naked eye. Right here is where the failure in alignment above complained of begins. A new road may evidently be thus quite at fault. And the more the track is doctored in after years for setting, treated with fresh ballast etc., the more it may get into error. As this almost reconstruction of the track is usually placed in charge of men of no high degree of mechanical judgment, or ocular precision, it is no great wonder that some roads ride very badly. It is very likely that the greater portion of the men who have this trimming of the track in direct charge, have no appreciation of any importance as attaching to the vertical alignment, each rail line being simply kept straight as viewed from above. But as the latter adjustment should receive especial attention as compared with the other, as previously pointed out, it seems to follow that the undenominated rule in practical force for the adjustment of tracks is about thus: *the attention given to each element of adjustment of railway lines is inversely as its importance.*

So far the comfort of travelers has been the chief point of argument. But no great stretch of thought is required to enable one to perceive that errors of track line are sources of danger. No railway train could follow a ram's horn at 50 miles an hour, or even 30. The tendency is not only to derailment, but to breakages of rails, axles, etc. A computation will show that in a train moving at the rate of 50 miles an hour; as any train averaging 30 may, occasionally, when passing over a convex vertical curve whose radius is less than 168 feet, the engine or car will leave the track altogether, and actually fly to where the rail makes its return to line. A jolt and a concussion is of course the result. Conversely at a concave vertical curve, with the same radius of 168 feet, the train will receive such a sudden bounce as to cause the strains upon rails, axles, etc., to be just double what would exist for a perfect track. The effect upon culverts and short bridges slightly out of line, where the speed is not slackened, can be imagned, if not guessed at.

The above considerations apply to straight tracks. As regards curves it is easily seen that greater difficulty will be encountered in attempting to secure perfect adjustment of rails. One fact in connection with the elevation of the outer rail should be noticed here. Doubtless many an observing traveler has noticed a considerable side thrust of car at striking the initial points of a curve. Also the termination of the curve is noticeable. If, however, the speed of train and elevation of outer rail be adapted to each other, it would seem that this should not be. The point to be noticed here is that in practice the center line of curve is usually made tangent to the center line of the adjacent straight track. This should not be so, because evidently the car should be so carried around the curve as to cause the least disturbance to its mass. To this end it appears that the center of gravity of a car should be so carried around the curve as to describe a path which is tangent to the adjacent straight branches. This is not the case in practice, the curved part of path being inside of its true position. To secure this tangency which is necessary for the best conditions, it will be necessary to set the rails outward, at curves, to an extent determined with due regard to the difference of level of rails, and height of center of gravity of car above road bed. Also one rail should be elevated, and the other depressed, instead of simply elevating the outer rail.

It would seem that all these desirable qualities of a road could not be secured short of the aid of a sort of preparatory school for section bosses, in which they are to have their understandings sharpened as regards proper adjustment of rails to line, consequences of error, etc. The weight of responsibility placed upon them should be more dependent upon their success at the school. Certain simple instruments should be introduced into rail-line adjustment, and instruction in their use given at the school. For instance, to facilitate vertical adjustments, a simple mirror placed edge to rail, and at an angle of 45°, would enable the adjuster to sight along a line of rail by simply looking downward. An attendant can then be sent along to different points and note them for high or low. Another device should also constantly be in hand, which, by a level, will give the relative heights of the rails at opposite points. It could consist of a cross-bar of gauge length, with a leg at each end, and a level swinging to different settings. In use, one leg is placed on each rail line, with level at the proper point for "straight" or "curve," etc. An instrument might also be devised, having a telescope or not, which could conveniently be so set as to lie in the line of a straight track, or swing in the plane of a curved track. Then, with a rod of a length equal the height of instrument above rail, one could detect inequalities in line of curve.

Finally, it might be stated, that as a matter of fact the riding quality of different roads varies greatly, some of which are already nearly faultless. This would indicate that if all the men who trim up tracks were equal to the best, the comfort of passengers would be greatly increased, accidents diminished and discrimination between roads mostly disposed of.

THE ELECTRIC LIGHT.

By F. E. NIPHER.

In the *Philosophical Magazine* for January, 1879, p. 30, Mr. W. H. Preece gives a discussion in which he shows the condition to be supplied in electric lighting, in order to obtain a maximum effect. In eq. 2, p. 31, he gives for the heat distributed to the incandescent material

$$H=\frac{E^2 l}{(\rho+r+l)^2}$$

where ρ represents the battery resistance, and r and l represent the resistances of the connecting wires and incandescent lamp, respectively.

For n lamps joined up in series, we must substitute nl for l, while if joined in multiple arc, we must put $\frac{l}{n}$ for l. In either case, the value of H is found to be a maximum, when the resistance of the lamp system is equal to that of the rest of the circuit.

Mr. Preece then proceeds on the assumption that this condition cannot be complied with, if n is large, reaching the conclusion that the amount of heat liberated in each lamp, varies inversely as the square of the number of lamps. This is true in either of the two cases discussed by him.

If, however, we have n lamps, arranged in n' parallel circuits, in each of which we have n'' lamps, the previous equation becomes

$$H'''=\frac{E^2 \frac{n''}{n'} l}{\left(\rho+r+\frac{n''}{n'} l\right)^2}$$

With this arrangement it is *always* possible to supply the condition which makes H''' a maximum, entirely irrespective of the value of n. If

$$\rho+r=\frac{n''}{n'} l$$

we shall have

$$H'''=\frac{E^2}{4(\rho+r)}$$

or the total heat in n lamps, is independent of the number of lamps.

The heat generated in each lamp will then vary inversely as the number of lamps.

ST. LOUIS, Dec. 30th, 1879.

SCIENCE AND APPLIED SCIENCE.

From "The Engineer."

It will probably surprise both engineers and grammarians to be told that applied science is not science. Nevertheless that is the doctrine which, at the present day, appears to be commonly held and even openly asserted. Of the latter fact two instances have lately come under our own notice. The first is one with which most of our readers will be already acquainted. The Institution of Civil Engineers has been lately sued in the courts of Westminster, to obtain payment of local rates on the ordinary seale corresponding to the house which it occupies. It of course declined the payment on the ground that, as a scientific society, it were exempted by Act of Parliament from such rating ; but it was contended on the other side that the Institution was not a scientific body under the meaning of that act; and the real basis of this contention—stripped of certain side issues, easily to be explained—was briefly that the object which the Institution sought to promote was not science at all, but simply the art of the engineer. The second instance grew out of the proposal made last spring by Dr. Siemens, that the societies having applied science for their object, should be gathered together into one central building. In discussing that proposal it was generally admitted that the means at the disposal of those societies, including the munificent sum offered by Dr. Siemens himself, fell short of the full amount required to purchase a site, and erect a building such as would be really worthy of the occasion. It was not unnaturally suggested that Government, in some form or other, might be asked to make up the deficiency; and that the great range of buildings at Burlington House, presented by the nation free of cost to the Royal and other scientific societies, formed an admirable precedent for the granting of the request. But it was immediately answered that this precedent did not apply ; that there was an essential difference between the two groups of societies ; and that what the Government had done for the one group, whose members were votaries of pure science, they would by no means be inclined to do for the other group, whose members cultivated an art, and even in many cases made their livelihood by its cultivation. The importance of the issue even in the first case is not inconsiderable. The annual amount demanded of the Institution of Civil Engineers was not small ; and of course the decision will affect all kindred societies which have now, or may have hereafter, houses of their own. But the importance af the second case is very much greater. It involves—as we shall show presently—the whole decision of the question, whether there shall be a central house of applied science in London or not ; and further, it involves the general estimation in which applied science is to be held, and the attitude to be taken towards it by Government and by the public. We therefore propose to devote a few moments to the consideration of the subject.

What is the difference between a science and an art? Surely not—as these objectors would have us believe—that an art is applied, or in other words, is practically useful, and that a science is not. Such an assertion is disproved at once, if it needs disproving, by a glance at the "Proceedings" of any of our scientific societies. For example, among the galaxy of pure sciences represented at Burlington House, the Chemical Society holds a distinguished place. Among the transactions of that society we may easily find side by side, say, a paper by Bessemer or Siemens on the chemistry of steel, and a paper by some little known chemist on some less known mineral, lately found in infinitesimal quantities in Siberia. We have no wish to depreciate the scientific value of the latter contribution ; but is the scientific value of the former less, because it may also be of enormous importance to the whole iron industry, and so to the world at large ? Or again, supposing that we read, in the Proceedings of the Royal Society, the announcement of a paper on " The strains in a metal or wooden curved bar, under a pressure normal to the surface, the bar being hinged at one end and having the other cut at a certain angle and resting against a similar bar." Would anybody doubt or deny that this was a strictly scientific paper on a somewhat abstruse point of the theory of elasticity? Yet this is precisely the subject of a paper which the Institution of Civil Engineers has been lately considering, only that it was described more shortly and simply as "Dock Gates." It is true that, by handling the question under the concrete form of "Dock Gates" the author was compelled to introduce a number of further consideratiens which largely increased the complexity and difficulty of the problem; it is rather hard if they are to be held also to deprive it of its scientific character.

In point of fact the distinction between art and science is nothing of this kind. The true distinction needs only to be stated in order to command assent. It may be expressed shortly by saying that science thinks, art acts. Science works by laws, art by rules. Science can be learned almost entirely by books; art almost entirely without them. Art instructs in the doing of a particular work; science investigates the principles on which the doing of it rests, and applies these to show how it may be done in the best possible way. A subject may be pursued almost entirely by art, or almost entirely by science; but very little work of real value is achieved without a union of the two. Let this real distinction once be apprehended, and it will be seen how it clears up the question at issue. Doubtless there is an art of engineering, and one which it is essential the engineer should learn; but wherever he may learn it, certainly it is not within the walls of the Institution of Civil Engineers. He learns it in the workshop, or in the field, and in the only way in which it can be learnt—that is, by the exercise of his own hands and his own eyes. He goes to the meetings of the Institution of Civil Engineers, and of kindred societies, not to learn the art of his profession, but the science of it; the science which will enable him to extend and apply his art to the best advantage. It follows that all such societies are, primarily and strictly, scientific associations. Doubtless in the communications read before them there is much—though far less than formerly—which deals exclusively with practical facts, and seems at first sight to be apart from science altogether. But the reason of this is that the subject matter of engineering is exceedingly complex and obscure. Its problems, traced to the source, nearly all lead up to some of the most abstruse branches of molecular physics. Science is as yet only groping her way amongst these problems, and it is impossible she should grapple with them successfully until she has a much larger number of facts at her command than she has at present. This is a complete justification of papers of a so-called practical character, so long as they do adduce new facts, and are not merely descriptions of what has been described before. Nor are these peculiar to engineering. In every branch of science papers recording experiments are eagerly welcomed; yet what are experiments but facts? A paper before the Chemical Society, for instance, can scarcely ever be anything but a record of ascertained facts; for as regards the discovery of laws, chemistry is far behind engineering. If, then, we were asked to define in one phrase what should be, and is, the main object of the Institution of Civil Engineers, we should state it as being to make engineering less of an art and more of a science. To such an object is science to refuse her recognition?

What we contend then is that engineering is looked at in its wrong light when it is viewed as a trade, or at the best an art—a mere matter of rule and practice; and that to be looked at in its right light it must be viewed—like chemistry or electricity—as a great and difficult science, the application of which happens to be of invaluable practical importance. It is just because it is commonly looked at in the wrong light that men have scouted the idea of public money being granted for a House of Applied Science; and conversely, it is just because engineering would thereby be put at once and forever in its right light, that we wish a House of Applied Science erected out of funds partly supplied by the public. Such a house would be a standing record of the fact that England recognized engineering as a science, and as a science to which she was herself indebted.

EXPERIMENTS ON THE TRANSVERSE STRENGTH OF SOUTHERN AND WHITE PINE.

By F. E. KIDDER, B. C. E.

Contributed to VAN NOSTRAND'S MAGAZINE.

THESE experiments were made under the auspices of the Scientific Society of the Maine State College during the months of October and November, 1879; and were running day and night for about forty days.

The pieces experimented with were: 1st. Five pieces of Southern or yellow pine (*pinus pâlustries*, L, or *pinus australis**), obtained from a lumber dealer of Bangor, Me., and stated to have been drying for four years, and also to have been kiln dried soon after being cut. These pieces were all taken from the same piece of plank, and were straight grained, and of an excellent quality. Their dimensions are given in Table A.

2d. Four pieces of white pine (*pinus strobus*) obtained from the same place as the Southern pine, and said to be of the same state of dryness. This lumber was cut on the west branch of the Penopscot river. All these pieces were also taken from one plank. These pieces would have been perfect but for some sap wood along one side.

3d. Four pieces of white pine taken from a plank which had lain three years in the attic of a hall, and which seemed to be very dry. These last pieces were almost perfect.

All of the pieces experimented with were of a very fine quality and were much better than can generally be obtained in large pieces.

As the pieces differed slightly from each other, it is thought best to give the quality of each, considering them all to be dry.

The principal object of these experiments was to obtain values of the modulii of rupture and of elasticity of these woods, of which the writer has never seen any satisfactory values published, and also to note anything that seemed to have any effect on the strength of the wood.

The method of making the experiments was as follows: The pieces were supported on two cast-iron frames, very carefully leveled, and placed exactly 40 inches apart. A scale pan was arranged so that it could be suspended from the middle of the beam by a $\frac{3}{4}$-inch bolt resting on the top, and could be raised from or lowered on to the beam by means of screws, as slowly and as gradually as could be desired. The deflections were obtained by fastening a vertical scale to the side of the piece at the center, and stretching a very fine silk thread across between the supports. By this method the deflections could be read to the hundredth of an inch. Although this method of obtaining the deflections was not as accurate as could be desired, yet the results show, I think, that it could have given rise to but very little error. In arranging for these experiments, and while making them, the writer was greatly assisted by Prof. Pike of the State College, for which he would here make acknowledgment.

To obtain the modulus of elasticity, each piece was subjected, at intervals of one or more hours, to loads of 27, 37 and 47 pounds, and the deflections noted.

The modulus was obtained from the deflections by means of the formula:

$$E = \frac{W\,l^3}{4\Delta BD^3},$$

in which E=modulus of elasticity, l=the distance between supports in inches, Δ=the deflection, B the breadth, and D the depth, also in inches. The value of Δ used was the mean of the three values for each piece, and W was taken at 37 lbs. The sizes, deflections and modulii of the different pieces are shown in the following table:

* Determined by Mr. Ed. T. Bouve, of Boston, Mass.

Piece.	Kind of Pine.	Quality.	Def.	B	D	Deflections. 27 lbs.	37 lbs.	47 lbs.	Mean Def.	Value of E.
			in.	in.	in.	in.	in.	in.	in.	lbs.
No. 1	Yellow	Perfect	40	1.24	1.24	0.11	0.14	0.19	0. 14$\frac{2}{3}$	1,707,282
No. 2	"	Fair	40	1.23	1.24	0.10	0.14	0.185	0.142	1,777,719
No. 3	"	Good	40	1.23	1.23	0.10	0.14	0.19	0. 14$\frac{1}{3}$	1,804,487
No. 4	"	Perfect	40	1.23	1.23	0.10	0.14	0 17	0. 13$\frac{2}{3}$	1,892,510
No. 5	"	Excellent	40	1.24	1.24	0.10	0.13	0.16	0. 13	1,926,161
No. 6	White	Excellent	40	1.5	1.5	0.06	0.08	0.11	0. 08$\frac{1}{3}$	1,403,259
No. 7	"	Good	40	1.49	1.49	0.07	0.10	0.12	0.096	1,251,252
No. 8	"	Excellent	40	1.49	1.49	0.07	0.08	0.115	0.088	1,365,002
No. 9	"	Excellent	40	1.5	1.5	0.06	0.085	0.11	0.085	1,375,746
No. 10	"	Excellent	40	1.5	1.5	0.06	0.08	0.11	0. 08$\frac{1}{3}$	1,403,259
No. 11	"	Perfect	40	1.5	1.5	0.06	0.08	0.10	0. 08	1,461,728
No. 12	"	Excellent	40	1.5	1.5	0.06	0.08	0.11	0. 08$\frac{2}{3}$	1,386,000
No. 13	"	Excellent	40	1.5	1.5	0.06	0.08	0.10	0. 08	1,461,728

Average value of E for yellow pine, 1,821,630.
" " " " " white pine, 1,388,497.

From this table we see, 1st., that the deflections are proportional to the weights, the dimensions being the same; 2nd. That for the pieces of yellow pine, the values of E varied from 1,707,282 lbs. to 1,926,161 lbs., and average 1,821,630 lbs; and 3rd. That the values of E for the pieces of white pine, vary from 1,251,252 lbs. to 1,461,728 lbs., and average 1,388,497 lbs.

In breaking the pieces, a washer of about 1$\frac{1}{4}$ inches outside diameter, was placed over the bolt that rested on the piece, to prevent its cutting into the wood. The pieces were not all broken in the same manner. Some had heavy loads resting on them for several hours, while others were broken in a comparatively short time. Very complete notes were taken of the deflections under the different loads, the length of time they were applied, the length of time between any two successive loads, the manner in which the pieces broke, etc.; but it would occupy to much space too present them here.

The following table gives the deflections of the pieces, under a few of the loads, the length of time the loads were allowed to rest on the beam, the breaking weight, ultimate deflection, when it could be observed, and the modulus of rupture R.

In all the above cases, the deflections

Piece.	Weight.	Time.	Def.	Weight.	Time.	Def.	Breaking Weight	Ultimate Def.	Modulus of Rupture R.
	lbs.	h. m.	in.	lbs.	h. m.	in.	lbs.	in.	lbs.
No. 1	125	17 00	.54	150	17 00	.68			
"	200	40 00	.91	250	17 00	—	390$\frac{3}{4}$	1.84	12,291
No. 2	Thrown	out, on ac	count	of gnarl	in wood.				
No. 3	275	16 00	1.20	300	0 05	1.36			
"	320	0 05	1.44	337	0 05	1.66	402	——	12,967
No. 4	350	1 30	1.20	380	22 00	1.74			
"	390	18 30	1.90	423$\frac{1}{2}$	0 05	2.00	454$\frac{1}{2}$	2.18	14,654
No. 5	390$\frac{1}{4}$	0 00	1.72	Broke in	1h. 30 min.		390$\frac{1}{4}$	——	12,280
No. 6	200	17 00	.46	300	1 00	.73			
"	385	1 30	1.07	430$\frac{1}{2}$	1 15	1.43	454$\frac{1}{2}$	——	8,080
No. 7	390$\frac{1}{4}$	0 40	1.20	404$\frac{1}{4}$	2 15	1.40	439$\frac{1}{4}$	1.60	7,973
No. 8	423	12 00	1.48	478	0 00	1.68	495$\frac{1}{2}$	2.12	8,982
No. 9	390$\frac{1}{4}$	0 00	.88	430	0 00	1.12	492$\frac{1}{4}$	1.72	8,751
No. 10	392$\frac{1}{4}$	40 00	1.30	403$\frac{1}{4}$	4 00	1.40			
"	412$\frac{1}{4}$	2 00	1.42	421$\frac{1}{2}$	16 30	1.79	440	1.91	7,822
No. 11	390$\frac{1}{4}$	0 00	.86	502	0 00	1.32	531	1.92	9,440
No. 12	415$\frac{1}{4}$	16 00	1.64	428$\frac{1}{4}$	0 00	1.70	436	1.90	7,751
No. 13	404$\frac{1}{4}$	1 05	1.12	415$\frac{1}{4}$	0 00	1 20	426$\frac{1}{4}$	1.24	7,578

Average value of R for yellow pine, 13,048 lbs.
" " " white " 8,297 "

are those taken at the end of the time the weight was allowed to rest on the beam, being sometimes much greater than when the weight was first applied. The value of R was computed by the formula $R=\frac{6Wl}{4BD^2}$, in which W the breaking weight, and the other letters have the same values as in the formula for E. Although these experiments were not sufficiently complete to determine any law regarding the diminution of the breaking weight, by subjecting the piece to frequent strains, not sufficient to break it, yet it seems to me that they show very plainly that the breaking weight is considerably lowered, by subjecting the piece to such strains.

As a result of these experiments, I find for the average values of:

The modulus of elasticity of the yellow pine...	1,821,630 lbs.
The modulus of elasticity of the white pine....	1,388,497 "
The modulus of rupture of the yellow pine...	13,048 "
The modulus of rupture of the white pine....	8,297 "

These values are larger than those given by earlier experimenters on American woods; but the values for the yellow pine, are somewhat less than those obtained by Prof. R. H. Thurston, as published in the *Journal of the Franklin Institute*, for October, '79. The values given there are:

	E.	R.
White pine	883,636 lbs.	5,280 lbs.
Yellow "	3,534,727 "	16,740 "

The value of E for yellow pine is certainly larger than that given by other authorities for *any* wood. The white pine, he states, to have been of a poor quality, which probably accounts for the low values of E and R.

In an article, published in Vol. XIX, page 8, of this Magazine, Dr. Magnus C. Ihlseng gives as the values of the modulus of elasticity of two pieces of white pine, determined by means of vibrations, 1,278,100 lbs. and 1,577,890 lbs. Taking the mean of these two values, 1,427,990, it does not differ very greatly from the average value derived from these experiments. Although these experiments are not complete enough to determine the true values of E and R, for perfect pieces of wood, yet it seems to me, that the values obtained are perfectly safe for use in calculation, and are more correct than most of the values now published.

ABSOLUTE ZERO OF TEMPERATURE.

By DE VOLSON WOOD, A. M., C. E.

In the November number of this Magazine, on p. 368, we find the following, taken from the *Revue Industrielle*:—"In the present state of our knowledge of the subject, nothing justifies the assumption of an absolute zero, and it is one of those false assumptions that tend to retard the development of science." An examination of the reasoning of that writer shows that he is not warranted in making his conclusion. He sets up a man of straw and proceeds to demolish him. He says, "consider for instance a gas whose volume is unity at a certain temperature. If the temperature be raised one degree, the volume will become $1+\alpha$; if raised one degree higher, its volume becomes $1+\alpha+\alpha(1+\alpha)=(1+\alpha)^2$, &c." Here is the fallacy. Experiment shows that the volume, in the second case, will be $1+2\alpha$; and generally $1+\alpha t$, instead of $(1+\alpha)^t$ as given by that writer. No explanation is given—it is a bare assumption.

The absolute zero of temperature, if it be a reality, is not within the limits of experiment. But if it has no real existence, it is not necessary to abandon its use, so long as the quantities reckoned from that point *are true within the limits employed in practice.* That they are practically true within these limits, has been abundantly verified by experiment. That the law would change if the temperature could be reduced to near the assumed absolute zero is not improbable; but since the lowest temperature ever observed is more then 200° above that point, and as this is many degrees lower than is actually reached, it is not necessary for the engineer to inquire what might take place if the temperature could be reduced to 10°, 50°, or even 150° above zero—although it may be a matter of speculative interest to the physicist. Practically, the absolute zero is a reality.

ERRATA.—In the article on "Arch Bridges," in the January issue of this magazine, certain typographical errors require correction, as follows:

On page 35, first line should read S=, &c.

In the eleventh line, "*dx*" should end the 10th line.

In the sixteenth line, "*slightly*" should be *directly*.

On page 37, Eq. 9 should be

$$y'+y''=y \quad (9).$$

On page 37, in Eq. 10, the denominators of the exponents should be n instead of x.

Also in the seventh line from the top of the second column of page 37, 5x110 should 5×110.

On page 38, in the parenthesis of the eighteenth line of second column, the word *one* should be *our*.

The same correction is required in the twentieth line from the bottom of the first column of page 39.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS CLUB OF PHILADELPHIA.—At a meeting of the Club held December 20th, Mr. Fred Lewis read a most valuable paper "On the Angular Pitch of Square-threaded Screws." When the screw is used as a means of conveying power, the square thread is the common and approved form, but no special standard of pitch is strictly adhered to, and inclinations ranging from 5° to 30° are often used. The efficiency of a screw is increased by the reduction of its frictional work, which will be found to depend upon the coefficient of friction, the angular pitch of the thread, the shape of the thread and the diameter of the supporting step or collar.

It is therefore desirable, in cases where the screw is used to convey power, that its frictional resistances be reduced to a minimum; and it was the object of this paper to investigate the relation between angular pitch and frictional work, and to derive a general formula by which the angle corresponding to the least amount of frictional work can be determined.

After elaborating the formulæ, Mr. Lewis has constructed two diagrams, from which one can readily find the most advantageous pitch with least sacrifice of power or material for a screw.

In diagram 2 it is shown that by a change from an ordinary collar to stepbearing, that a screw whose pitch was 5° might be increased to 13° without sacrifice of power and with a saving of .6 of the work consumed by friction.

Mr. Lewis cited many instances in which the application of the formula for determining the pitch of screws would lead to a great saving of power, and also gave a full description of apparatus used and manner of conducting his experiments.

A communication from M. Pontzen, of Paris, requesting information upon the the subject of narrow gauge railroads and street railways was read. The Secretary will be very glad to receive any information or data upon these subjects either from members of the Club or others, and due credit will be given for such.

Prof. Lewis M. Haupt exhibited a new form of transit rod, which consists of a hollow brass rod about ¾ inch in diameter, loaded at one end, and held by the rod man with a thimble joint. Its perpendicularity is thus insured, and its small size makes it a much more accurate instrument than the old style wooden rod. The rod has been used extensively and found perfectly satisfactory. Its weight is about the same as an ordinary ash rod.

Mr. Hering introduced Messrs. Vaux & Clime, who exhibited and explained to the Club a new form of turbine, which it is claimed gives much better results in practice than the old forms.

Mr. Hering also exhibited a trap-valve for preventing the escape of foul air into houses from closets, sinks, etc., which has been invented by Mr. Gorman. This valve is made upon the same principle as a sewer trap described to the Club last spring by Mr. Gorman. It is a balanced valve, consisting of a plate, hung on brass axis fastened in back part of pipe. The counter-weight in the valve is adjusted by a filling of lead, according to the number of wash-stands, closets, etc., about the valve. By allowing the valve to strike against a lead-bearing a tight joint is always obtained.

Mr. Ashburner read some notes upon a recent test of aneroid barometers which he had made in the East Norwegian Shaft, near Pottsville, Pa. The shaft is 1585 feet deep. In descending the shaft, the Hicks barometer which he carried marked 1590, and in ascending, 1575. Mr. A. said that this is the most accurately working barometer he ever carried, and in the experiments he had noted a number of points which he thought might be of practical value. The instructions given in most text books are that it is necessary, after making a rapid ascent or descent, to allow a few minutes for the barometer to come to its bearing, but it was noticed in these experiments that the instrument came to its bearing inside of ½ minute, and did not change in the next ten minutes. Instances of remarkably good results in obtaining elevations by barometric work were cited by Messrs. Ashburner, Young and Billin, and general discussion ensued.

Mr. Billin read extracts from a translation by himself of a very interesting paper on Dephosphorization of Iron, read by Mon. Gautier before the Society of Civil Engineers of Paris.

IRON AND STEEL NOTES.

In former times it has been observed, when iron was made in small forges and at comparatively low temperatures, in a similar manner to that still employed in certain half-civilized countries, the greater part of the phosphoric acid passed into the ferriferous slag, and good malleable iron was finally produced tolerably free from phosphorus. The following is an analysis of a scoria produced in Roman or Etruscan times from the specular ore of Elba, which usually contains about 0.04 per cent. of phosphoric acid:

Iron protoxide	76.49	per cent.
Alumina	2.57	"
Manganese protoxide	0.60	"
Lime	1.32	"
Magnesia	0.64	"
Zinc oxide	0.20	"
Sulphur	0.40	"
Phosphoric acid	0.34	"
Silica	14.20	"
Oxygen and not estimated	3.88	"
	100.00	"

This specimen was taken from a large heap of many thousands of tons of scoria lying on the beach close under the site of Populonia the Etruscan Pupluna, a town much famed in those times for its iron and copper manufactures. It furnished Scipio with iron in the second Punic war. It is now a deserted site, and but few traces of its former importance remain.

It is of interest to observe in the above analysis that the phosphoric acid is about eight times as much as in the natural ore.

I obtained in February, 1878, a piece of metallic iron from the same district; it originally weighed about 2 kilos., and was somewhat rusted. It was found among scoria in the vicinity of Campiglia, and gave on analysis:—

Combined carbon	0.873	per cent.
Graphite	2.853	"
Silicon	0.544	"
Sulphur	0.096	"
Phosphorus	0 090	"
Manganese	0.091	"
Iron sesquioxide	2.430	"
Metallic iron	92 804	"
Moisture	0.092	"
		"
	99.873	"

Of the antiquity of this specimen there is some doubt, but it has certainly not been produced in recent times. The high percentage of carbon cannot be adduced as indicative of its modern origin; the researches of Lowthian Bell proving that carbide of iron in contact with iron oxide in the molten state is not necessarily decarburised. Similarily, therefore, the above specimen might have been made contemporaneously with a richly ferruginous scoria, such as the Roman or Etruscan metallurgists produced. The ancients possibly new iron both cast and wrought, as well as the intermediate steel. Pliny says that iron was made in a similar manner to copper. Making a comparison between puddling and copper smelting, he notes the "remarkable fact that when the ore is fused the metal becomes liquefied like water, and afterwards acquires a spongy brittle texture" (xxxiv., 41), which goes to imply that iron first "came to nature" considerably previous to the days of Mr. Cort.

Cast-iron recently produced from Elba ore near the same locality contained three times the quantity of silicon present in the above analysis, the constituents being as follows:

	I. Per cent.	II. Per cent.	Mean Per Cent.
Carbon	4.306	4.147(diff.)	4.306
Silicon	1.672	1.676	1.674
Sulphur	0.067	0.056	0.067
Phosphorus	0.110	0.108	0.109
Manganese	0.748	0.757	0.753
Iron	93.256	93.256	93.256
	100.159	100.000	100.165

Large Forgings and their Materials. The object of this paper by Mr. G. Ratliffe, is to show that a forging made from built-up and welded steel blooms, being of a fibrous and well-worked character, is better than a forging from a single cast ingot. It is, he says, most important to convert the crystalline into as fibrous a nature as possible, and this is better done by rolling than by any other known process. He now takes the ingots, made of a specially mild quality of steel, and rolls them down to bars, so that a fibrous material is the result, and the crystalline structure of the ingot is got rid of. These bars are sheared into suitable lengths, and piled together in order to make the required forging. Keels, stern-frames, and other forgings, of awkward shapes, can now be made of steel, and vessels built entirely of this material, where hitherto they have been only partially so constructed, with great disadvantage in several respects. The author gives the results of a large number of tests of the material described. which are of a very highly favorable character. He urges the necessity of using a very ductile steel for forgings, objects to the use of single cast ingots because of the great difficulty in working them, and in illustration of the apparently unsatisfactory character of hard steel for some forgings, referred to the recent report of the Board of Trade on railway casualties, which shows, among other things, that "of the thirty-six crank or driving axles, twenty-four were made of iron and twelve of steel The average mileage of twenty-one iron axles was 193,999 miles, and of ten steel axles 168,472 miles." As there may be a very great many more iron axles running at the present than there are of steel, the above figures do not speak very much in favor of steel for this use; but the failures would probably have been very considerably less if the steel had been worked and welded as described.

Respecting iron forgings, Mr. Ratliffe says, that as most of the scrap from which these are made is shipyard scrap it is of a very common quality, and cannot make good ductile iron. The best selected scrap is, he says, uncertain; and owing to the varying qualities of iron we are so liable to get, we cannot insure a material of uniform quality, but often find seams or black marks, which are by so many engineers considered sufficient to condemn almost any finished shafting.

The author stated that the cost of making forgings of mild welded steel is considerably less than that of making them from large ingots, and that it gives the further advantage of certainty that the material is properly worked, which, he contends, is not the case with an ingot. The author described some experiments made by exploding charges of gunpowder in cylinders of the welded steel, with the object of showing its suitability for guns and armor-plates, experiments that might suggest its suitability for the former, but useless as indications respecting the latter.

RAILWAY NOTES.

STEAM TRAMWAYS IN ITALY.—The line Bergamo-Treviglio Lodi has been open to the public from Bergamo to Treviglio since the 1st September, and the other half from Treviglio to Lodi is now in course of construction. The provincial road on which the rails are laid, is more solid than any other known, and so hard that in many places blasting was employed for laying the sleepers. The gauge is the same as adopted for all Italian railways, viz. 1.445 metres. The rails, supplied by one of the first works in Rhenish Prussia, are of Bessemer steel, and weigh 18.600 kilogs. per running meter. The accessories for fixing the rails were made in Italy. The sleepers are of the following dimensions—2.30 by 0.17 by 0.12 meters, and altogether of the best and soundest oak of Lombardy. The carriages are of first, second, and third class, both closed and open on the sides—called *jardinieres*—and closed, and open trucks for the transport of goods and cattle; all of these are built by a firm in Milan, which has supplied the rolling-stock to almost all similar lines in Italy, and is now building the carriages for account of the Tramways and General Works Company in London, who are constructing a line in continuation of the Tramways Pistorius. Tramway extension is already occupying a great deal of attention in some of the chief Italian cities, and the value of light railways, as means of intercommunication between villages and towns in directions not served or likely to be served by railways, is generally acknowledged. The engines are of the well known factory of Messrs. Henschel and Son, in Cassel, Germany, The trains are usually composed of four carriages, capable of carrying on an average 150 passengers each journey. The rails are laid in a single line on one side of the high road, and in the villages there is a double line for the depth of about 80 meters. The goods service is done during the night. At the extremities of the line, in Bergamo and Lodi, and in the central point at Treviglio, there is a passenger station composed of a waiting-room, buffet and office for the station master; also sheds for engines and carriages, which occupy an area of about 3,000 square meters. Besides there is at Treviglio a well-furnished repairing shop and magazine for sundry material. The line has a total length of about 45 kilometers, and passes through fifteen towns and villages. The above may give an idea of the nature and importance of the line. Whoever knows Italy and the high cost of ordinary railroads, must be convinced of the utility of the largest extension of such steam tramways.

THE *Inter-Ocean* has been collecting statistics of railway tunnels, and finds the more important of such structures to number 957, with a total length of 291 miles. They are distributed as follows: Great Britain, 140 tunnels and 87½ miles; France, 259 tunnels and 82.6 miles; Belgium, 20 tunnels and 4.07 miles; Germany and Austria, 270 tunnels and 51¼ miles; Italy, 76 tunnels and 19¾ miles; Switzerlaud, 5 tunnels and 4.08 miles; North America, 115 tunnels and 33 miles; South America, 72 tunnels, and 9 miles. Of English tunnels the most noted for magnitude and difficulty of construction is the Kilsby on the North-Western Railway, length 1.33 miles, cost $1,500,000, chiefly from nearly a fifth of its length being in quicksand saturated with water. The Nerthe tunnel in France is nearly three miles long, and cost $2,090,076; the Blaizy tunnel 2½ miles. The largest tunnels in Germany are between Offenburg and Constance. There are 15½ miles, 29 tunnels of various lengths, the longest 5,600 feet. The longest and most interesting tunnel in Switzerland is the Hanenstein, 1½ miles long. The one of chief interest in Italy is the Mont Cenis, 7¼ miles in length. The principal tunnel in America is the Hoosac tunnel, which is 4.75 miles in length. The Mont Cenis tunnel is the longest railway tunnel.

A CURIOUS contrast of the proportionate receipts and expenses on railways is afforded by some official statistics in regard to the Great Northern Railway—one of our typical passenger railways. These facts may correct some misapprehensions as to the sources of receipts and expenditures on railways, and the contrast afforded by little more than three years' working is instructive. Four years ago the receipts from passengers, parcels, mails, &c., were equal to 4.89s. per train mile; in the last half of last year—corresponding half-year—they were 4.28s. per train mile; and in the first half of this year they had sunk to 3.73s., it being always borne in mind that the latter half of the year is the more remunerative one. In 1875 the receipts from merchandise and mineral traffic were reported as equal to 5.48s. per train mile; in the corresponding half of last year the receipts from these sources were 5 52s. per train mile; and in the first half of the current year they were 5.39s. per train mile. Adding other slight items of expenditure, the receipts over the whole train mileage—passenger and goods—of the company were, in the earlier year, at the rate of 5.29s. per train mile; in the corresponding period of last year, 4.99s.; and in the first half of the present year, 4.69s. Thus though the gross receipts of the company are increasing, they are not increasing so rapidly as is the train mileage, the running of which earns them. As to the expenditure, the figures are instructive also. Four years ago the maintenance of way, works, and stations cost 6.20d. per train mile; in the corresponding half of last year it cost 5.91d.; and in the first half of the present year the cost was 5.63d. For locomotive power the charge was, in the earliest half-year named, 8.69d.; in the contrasting half of last year, 7.63d.; and in this year, 7.81d.—the change being chiefly due to the reduced price of coal. The traffic expenses are the costliest item; they were, four years ago, 11.18d. per mile; at the end of last year, 11.0d. per mile; and at the present time, 10.60d. per mile. Compensation has fallen from .78d. per mile to .67d. and .55d.; law charges are practically unchanged, and general charges have fallen .20d. per mile. The only noticeable increases are in the cost of repairs to carriages and wagons, and in rates and taxes. The total cost was, four years ago, 2.77s. per train mile; and, in the corresponding period of last year, 2.66s., whilst for the present year the amount has been 2.63s. The reductions, therefore, in the expenditure have not been so large as those in the receipts. In the cost of many materials there have been large reductions, but there has not been an application of the pruning knife so fully in other directions, and it is probable that on our chief railways the example set by the North British in the reduction of salaries and wages may have to be followed.

ORDNANCE AND NAVAL.

WOOLWICH AND KRUPP GUNS. On Thursday afternoon, August 11th, one of our 80-ton guns intended for the Inflexible was fired in the Royal Arsenal, with results which have been justly noticed in the daily papers as very important, though slightly exaggerated. It appeared satisfactory indeed that so soon after we had been astonished at the results obtained by Krupp's 71-ton breech loader, our own gun should even surpass its achievements, and this was stated to be the case now. However much we should naturally share in the satisfaction thus expressed at so good a result, it is necessary to examine the facts carefully in order to guard against the mistake of taking credit for something more than has been really achieved. Such caution is clearly called for when the first reports on which the commendations are based leave out what is absolutely essential to enable us to determine whether there is cause for congratulation at all. We refer, of course, to the *pressure* developed in the bore, which was not mentioned in any of the first reports. A very little thought will show the necessity for knowing this condition. We may surely all suppose that a considerable margin of strength must exist beyond that which will enable any gun to bear the strain of an ordinary service round. Suppose, then, that the Krupp gun obtains a result with what its maker considers its proper service charge, which result is better than that given by our own 80-ton gun fired with its own surface charge—it stands to reason that we may be able to fire a round with a larger charge than that for ordinary service, and so obtain a better result on any given occasion, without perhaps over-straining our gun. Such a round would be an exceptional one, whose results must be treated as exceptional, and which would mislead the public if not so described. Whether any actual experiment ought to be entered in such a catagory, or to be treated as good for general purposes, entirely depends on what pressure was exerted on the bore of the gun; if such pressure was low enough for the gun to stand habitually, it does not matter whether the round in question was supposed to be exceptional or not; for it is manifest that such conditions might for the future be allowed on service. It is clearly necessary, however, that we should know the pressure developed in the bores in order to compare the results obtained with any two guns. Now it happens that the round fired with the 80-ton gun was actually a proof round, not one intended to be employed ordinarily on service. It may be replied that we have no guarantee that Krupp's was not the same. Let us then come to the question of pressure, which, with the other conditions, will enable each result to speak for itself. In giving these results we have to make a correction in the weight of the projectile of the 80-ton gun as given in the daily papers, namely, a deduction of 60 lbs., and on that of Krupp's quoted with it, of no less than 74 lbs. At the same time we have to explain that, in going over the printed reports of the Meppen firing, with the results recorded on the ground, we find that we have in one case, by some accident, a wrong velocity printed, namely, 1602 feet instead of 1648 feet. It is well, then, to give here the actual conditions of each round concerned, as we believe to be correct, within small limits. The 71 ton Krupp gun at Meppen on August 5th, fired a projectile weighing 1,712 lbs. with an initial velocity of 1,648 feet per second; the pressure on the bore was 19.85 tons, the projectile having, consequently, 32,242 foot-tons of stored-up work. This, with the calibre of 15.75 inches, gives a penetrating figure of 651.61 foot-tons per inch circumference, and, with the ordinary formula and factors employed in the service, a penetration of 32.12 inches.

The 80-ton gun at Woolwich, on September 11th last, fired a projectile weighing 1,700 lbs. with an initial velocity of 1,657 feet per second, and a pressure of 21.5 tons, having 32,366 foot-tons stored-up work, which, with a diameter of 15.92 inches (taking the windage off the 16 inches), gives a penetrating figure of 647.15 foot-tons, and a penetration of 31.98 inches. Comparing these two, we see that the Woolwich gun has rather more stored-up work, and would strike rather the more severe blow of the two. This tells where actual penetration has not to be obtained, for example, against steel plates of suitable thickness. On the other hand, the Krupp gun would have rather more penetration. We may, however, call the two rounds equal to all intents and purposes, but can we say the same for the guns? The Woolwich gun has a pressure of 21.5 tons and the Krupp only 19.85 tons. If the former pressure is not considered too high, the question arises whether we ought not in fairness to take the most powerful round that the Krupp gun has fired, when such a pressure has not been exceeded, Now in our report we gave the highest recorded result with the 71-ton Krupp, which may fairly be compared with a Woolwich proof charge. This was a projectile weighing about 1,715 lbs. discharged with a velocity of 1,703 feet per second, having, therefore, 34,490 foot-tons stored-up work, a penetrating figure of 697.05 foot-tons, and a penetration of 33.50 inch, with a pressure of 20.92 tons. Now this result decidedly beats that obtained at Woolwich, the penetration is 1½ inch more and the stored-up work 2,124 foot-tons in excess, while this is obtained with considerably less pressure on the bore. We think, then, that few will contend that this result is not superior to that obtained by the 80-ton gun. At the same time there is something yet to be said on the subject in favor of the Woolwich gun, and this makes it necessary to compare the guns a little more carefully. While the 71-ton gun is the lighter of the two by nine tons, it is very much the longer, the actual bore of this gun being 343 inches long, and that of the 80-ton gun 288 inches only; that is, there is 4 feet 7 inches difference in length of bore. It is this that enables the Krupp gun to develop so much work at so low a pressure, because the powder gas has a longer time to act on the shot; but we must give the 80-ton gun its due. If the gun is shorter and heavier, it is of course much thicker, and ought, therefore, to be stronger. The advocates of steel may question this, but for the moment we must refuse to consider the respective merits of steel and wrought iron. We can only compare two guns by comparing their features one by one, and any question yet unsettled such as this must not be allowed to stand in the way, as any arbitrary value might be claimed by the advocates of each kind of metal which would make any definite discussion impossible. For the moment, then, putting the difference in the nature of the metal on one side, we have the Woolwich gun 4 feet 7 inches shorter and 9 tons heavier than Krupp's, and therefore thicker and capable, if made of equally good metal of resisting a greater strain than Krupp's gun. Probably no two people would agree as to exactly how much greater strain it might bear, but certainly a comparison with equal pressures may be fairly objected to. The question then is a complicated one; we have shown that no comparison can be made without considering the element of pressure, but we end by finding that it is impossible to know exactly how much to allow when we have compared the pressures carefully. Probably most artillerists, our own included, will consider that the Krupp gun has decidedly the best of the comparison, without being able to say the precise measure of the advantage. Why is this? The 80-ton guns have actually been completed more recently than Krupp's gun; might we not have looked for a better result? The answer to this involves what is at this moment perhaps the most important question connected with heavy guns, namely, that of breech and muzzle loading. We will explain why. The 80-ton guns, although only recently completed, had their proportions determined four years ago. Subsequent experience has taught us the great advantage of increased length and slower burning powder, but we were unable to avail ourselves of our knowledge in this particular instance, for the guns are made to suit a turret vessel which has in the meantime been built, and the length of the gun is involved in some of the leading dimensions of the ship, because it has to be loaded from the muzzle. Had the pieces been breech-loaders it might have been possible to have altered their dimensions and increased their length, because it is hardly ever necessary to approach the muzzle of a breech-loading gun. In action we have literally nothing to do with it. Whether or no a breech-loading gun, projecting further out of its turret than was originally intended, clearly matters little in comparison with the question of any alteration in the length of a gun that dips its muzzle and is loaded from a certain fixed place constructed in a deck every part of which has been carefully worked out, and which involves the design and structure of the ship itself. Once more, then, we are brought to see the advantages recently obtained by breech-loading guns over muzzle-loaders. We pointed out in our article of September 5th what an advantage the breech-loader had as the length became greatly increased, or again if the chamber were greatly enlarged; to these may be added that the length can be altered if desirable without necessitating any serious alteration in a vessel necessarily designed long before she is equipped; and, lastly, that it now seems to be acknowledged that the breech-loader has beaten its rival in accuracy of fire.

Once more, to return to the recent trial of the 80-ton gun, we may say that, regarded as an effort to obtain a good result from a gun whose length is certainly not what would be assigned to it in the light of recent investigations, the success has been great. By carefully chambering and adjusting the charge, much has been done to utilize thickness where we should have preferred length; but if we were to go further, and were to suppose that our 80-ton guns are better proportioned and superior to the guns recently designed at Essen or Elswick, we should make a great mistake.

ENGINEERING STRUCTURES.

INUNDATIONS AND EMBANKMENTS.—At a recent meeting of the French Academy, Gen. Morin made an interesting report on the works of Engineer Dausse relative to embankment of the Tiber at Rome. Extending the question, he studied the inundations of large rivers in general, with the best means proposed for preventing their terrible effects. The recent catastrophe which destroyed a populous city in Hungary renders the subject of much public interest at present.

At Rome, the flood of the Tiber in December, 1870, caused grave disasters. The ever-increasing obstruction of the river exposes to inundation several closely-populated quarters, and the principal public monuments.

An inquiry was set on foot by the Italian Government. The Commissioners thought they must exercise great reserve with reference to the solution of the problem proposed by M. Dausse, viz., deepening of the present bed of the river so as to restore the navigation, at present interrupted. The project of the Government was to keep the river, in its passage through Rome, between quay-walls 18 meters in height, and higher than the level of the neighboring streets.

Taking up, first, the question of the embankment of rivers, Gen. Morin indicates the inconveniences and dangers of certain arrangements that are thought to be preservative.

A study of the *régime* of great rivers is necessary in order to appreciate the real value and utility of embankments.

In rivers with movable bottoms there are often formed deposits which hinder navigation, not allowing sufficient draught of water. To prevent these deposits dredging is insufficient. According to General Morin, the best arrangement appears to be that which has been adopted in the lower part of the river Po.

Submersible dykes are formed on both banks of the river. The object of these is to protect against average floods the rich and fertile plains which are left in the greater bed of the river, and are called *golenes.* In order that the dykes in question may not prevent the waters of great floods from expanding over the whole width of the greater bed, it is prescribed that their top should be 1.50 meters below the great insubmersible dykes. These dykes, then, have the effect of narrowing the river in times when its waters are low, thus forming a channel, which M. Daussee calls a *duits.* Hence the velocity of the water is increased, having the effect of carrying off sand and gravel that would otherwise be deposited. In the floods of summer the waters of the river spread into the fluvian plains and fertilize them.

Similar dykes to those of the Po were formed on the Moselle in 1835, and by this means navigation is rendered possible between Metz and Frouard. At the mouth of the Somme the Compagnie des Chemins de Fer du Nord, by constructing dykes which have necessitated an expense of 515,000 francs, have succeeded in "conquering" from the ocean and transforming into cultivable land 502 hectares, representing a value of 1,740,000 francs.

The reporter points out, further, that the insubmersible dykes formed on the banks of great watercourses often occasion serious dangers, and he recalled the fact that in 1846 the Italian engineer, Paleocapa, when consulted as to the regularization of the course of the Theiss, had advised to leave between the dykes an interval of several hundred fathoms. His advice was not listened to; the dykes were constructed on the very banks of the river, and the terrible disaster of the town of Szegedin was the sad consequence.

En résumé, the large dykes should be placed five or six meters from the border of rivers and streams, so as to furnish to the inundation a space sufficient to extend itself in without danger.

Mention was made in the "Minutes of Proceedings" Inst. C. E., vol. lvi., p. 337, in a communication on the Aubois lock, of a proposal to use a hydraulic brake for causing the pipes, in the apparatus for saving water in locking, to drop quietly on to their seats without any shock or rebound. This has since been successfully accomplished, without the aid of a valve, by employing a brake consisting of a wooden inverted truncated cone moving in a vertical sheet-iron cylinder filled with water. The cylinder is 1 foot 8 inches high, and 8 inches in diameter; it is fastened at the bottom to an iron plate firmly fixed on the ground, and has a sheet-iron lid. The upper part of the cone, which is cylindrical for a length of ⅝ inch, has a diameter of 7½ inches, and a length of 8 inches. An iron rod is inserted in the axis of the cone; it is fastened by a nut at the bottom, and passes through a hole in the center of the lid of the cylinder, and has a cord attached to it at the top. When the counterpoise of each great movable pipe of the apparatus approaches its highest point, the cord attached to the cone is abruptly pulled tight, and the descent of the pipe is checked by the resistance the cone experiences in rising in the cylinder. The cone is sufficiently weighted by the rod to sink to the bottom of the cylinder when the cord is slackened. By increasing the distance traversed by the cone, the fall of the pipe on to its seat can be rendered as easy as desired, without its tightness on its seat, when once reached, being at all affected.

BOOK NOTICES

Medical Chemistry. By C. Gilbert Wheeler. Second and revised edition Philadelphia: Lindsay & Blakiston. For sale by D. Van Nostrand. Price, $3.00.

The present work begins with a treatise on the classification of organic compounds as in the author's work on organic chemistry. This, with the discussion of alcohols, ethers, acids and alkaloids make up half the volume.

Then comes a brief discussion of the proximate constituents of plants, and this is followed by a similar treatment of the proximate principles of the animal organism.

The book will prove convenient for a student who desires to refresh his memory upon a point of chemical constitution, but the work is not designed to satisfy the complete wants of a medical student.

Life and Work of Joseph Henry. By Frank L. Pope, Vice-President of the American Electrical Society, Member of the Society of Telegraph Engineers, etc., etc. Pp. 31. New York: D. Van Nostrand. Price, 50 cts.

This pamphlet is reprinted from the "Journal of the American Electrical Society," and it is especially interesting and useful as giving a clear account of Professor Henry's electrical and electro-magnetic investigations. We want a more considerable work in relation to the career and influence of Professor Henry, but in the absence of such a volume this paper will prove most instructive.

THE INTER-OCEANIC CANAL QUESTION. By REAR ADMIRAL DAVID AMMEN, U. S. N. Philadelphia, L. R. Hammersly & Co. For sale by D. Van Nostrand. Price, $1.00.

This subject is of absorbing interest at the present moment. That the various aspects of the question are fully considered, may be inferred from the following list of topics presented:

The sufficiency of our information in relation to the topography of the American Isthmuses.—The feasibility of an Inter-Oceanic Canal via Lake Nicaragua, as a commercial question.—The present aspect of the ship-canal question.—Proceedings in the general session of the congress in Paris, May 23, and the technical commission, May 26, 1879.—Report of Rear Admiral Ammen to the Secretary of State, June 1879.—Report of Civil Engineer A. G. Menocal to the Secretary of State, June 21st, 1879.

Thus, in compact form by the most competent authorities, we have the question presented, which now commands the attention of people of many nationalities.

ANALYSIS NOTE-BOOK By W. B. POTTER. St. Louis: Buxton & Kinner. For sale by D. Van Nostrand. Price, $1.50.

This is simply a laboratory note book, for the purpose particularly of recording quantitative analyses.

The pages are headed with the names of common objects of commercial assay, and the possible constituents are neatly printed in column on the left side.

A table of useful multipliers, and one of atomic weights are thoughtfully added for convenience of the analyst.

LINKAGES. THE DIFFERENT FORMS AND USES OF ARTICULATED LINKS. By J. C. DE ROOS. Science Series No. 47. New York: D. Van Nostrand. Price, 50 cts.

The subject of this little book has not as yet, occupied the attention of American scientists. The literature of Linkages is mostly in the German, French, or Russian languages. This essay has appeared in several languages of Europe. The unique, and extensive applications of mechanical methods to solutions of problems, formerly supposed to lie beyond the reach of such processes, proves to be very attractive to a certain class of students who delight to be early in any new field of research, especially where there exists, as in the present case, a possibility of reward in the way of original discovery.

COMMON SENSE IN CHURCH BUILDING. By E. C. GARDNER. New York: Bicknell & Comstock. For sale by D. Van Nostrand. Price, $1.00.

Arguments for and against decorative architecture are presented here, in the form of letters from imaginary correspondents.

Aside from a tendency to prosiness on the part of most of the writers, and a stilted form of pictism on the part of a few, the arguments of people who have not thought deeply upon this or any similar subject are agreeably enough presented.

The book is in an exceedingly neat form, and contains in its practical portions some good illustrations.

MISCELLANEOUS.

WE regret to announce that owing to the late fire at Boston, by which the printing establishment of Rand, Avery & Co. was partially destroyed, the publication of Mr. Shunk's new work, "The Field Engineer," has been unavoidably postponed. The printed sheets having been destroyed, it will be necessary to print it off again entire.

THE most important news of the past month in the world of science in the announcement by Mr. Maclear, of the St. Rollox Works, Glasgow, made to the Philosophical Society of that city. In a note addressed to that body, Mr. Mactear said that after a series of careful experiments, extending over a period of thirteen years, he had succeeded in obtaining crystallized forms of carbon. They were perfectly pure and transparent, and had all the refractive power of diamonds. They had the crystalline form of diamonds, and resisted acids, alkalis, and the intense heat of the blow-pipe. They also scratched glass; and the only other tests that remained to be applied were as to whether they could scratch diamonds or be scratched by diamonds, as to the refractive index of the crystals, and also the measurement of the angle of the crystals. These tests had not, as he had said, been carried out, but they would be shortly, and he hoped to put some of the speeimens before the Society on a future occasion. He had no doubt in his own mind, and neither was there any doubt in the minds of the scientific gentlemen (Profs. Tyndall and Smyth) whom he had consulted, that they were diamonds, but in the meantime he preferred to describe them as pure crystalline forms of carbon. The forms he had obtained were in size 1-32nd of an inch. They are in the hands of Mr. Maskelyne, of the British Museum, for rigid examination.

AN interesting paper on the discovery of ancient ironstone mines in the Cliviger Valley, Lancashire, and of the remains of old bloomaries in the immediate locality, was read by Mr. John Aitken at the meeting of the Manchester Geological Society on the 16th. The mines were of an extensive character, and had been skillfully laid out, but the period at which they had been worked could not have been less than two or three centuries back, as the entrances to them had been completely blocked up, and their existence almost forgotten in the neighborhood. The ironstone bands were similar in thickness but superior in quality to the well known Low Moor black band, and appeared to have been extensively got during the working of the mines. The remains of seven bloomaries were discovered in the neighborhood from three to seven miles distant from the mines, and these undoubtedly existed at the time of the Roman occupation.

ENGINEERS often want to mount a photograph. The following makes a good paste for the purpose. Mix thoroughly 630 grains of the finest Bermuda arrowroot, with 375 grains of cold water, in a capsule, with a spoon or brush, then add 10½ ounces more water, and 60 grains of gelatine in fine shreds. Boil, while stirring, for five minutes, or until the liquid becomes clear, and when cold stir in well 375 grains of alcohol, and five to six drops of pure carbolic acid. Keep it in well-closed vessels, and before use work up a portion carefully with a brush in a dish. It will keep for considerable time.

THE highest inhabited houses in the world are, says the *Scientific American*, in this country; one, a miner's house on Mount Lincoln, Colorado, is 14,157th ft, high. Another in Peru, a railway village, called Galera, is 15,645 ft. high. Near this place is the celebrated railway tunnel of La Cima, which is being bored through the peak of the mountain. The tunnel is 3,847 ft. long, and is 600 ft. above the level of perpetual snow.

CAST iron magnets are made by M. Carré by melting soft metal very slightly carburetted in crucibles, adding 10 to 15 per cent. of steel filings, and running it into moulds. If 1 to 1½ per cent. of nickel be added to the mixture, and 25 to 30-1000ths of copper, or 2 per cent. of tin, and 50-1000ths of copper, the moulded iron can be tempered at a cherry-red heat. The best result is obtained, however, says the *Electrician*, by tempering pure cast iron at as high a temperature as the moulded pieces will stand without distortion of fracture.

COLOGNE CATHEDRAL.—The *Cologne Gazette* says:—"The two towers of our cathedral are now the highest buildings on the earth; they exceed by 1.50 meters the tower of St. Nicholas Church, in Hamburg, which is 144.20 meters high. When completed they will measure 160 meters, reckoning from the pavement of the cathedral cloisters, or 157 meters reckoning from the floor of the church itself. The following are the heights of the most remarkable high buildings in the world:—Towers of Cologne Cathedral, 160 m. or 157 m. (524 feet 11 inches, or 515 feet 1 inch); tower of St. Nicholas, at Hamburg, 124.20 m. (473 feet 1 inch); cupola of St. Peter's, Rome, 143 m. (469 feet 2 inches); cathedral spire at Strasburg, 142 m. (465 feet 11 inches); Pyramid of Cheops, 137 m. (449 feet 5 inches); tower of St. Stephen's, in Vienna, 135.30 m. (443 feet 10 inches); tower of St. Martin's, at Landshut, 132·50 m. (434 feet 8 incnes); cathedral spire at Freiburg, 125 m. (410 feet 1 inch); cathedral at Antwerp, 123.40 m. (404 feet 10 inches); cathedral of Florence, 119 m. (390 feet 5 inches); St. Paul's, London, 111·30 m. (365 feet 1 inch); ridge tiles of Cologne Cathedral, 109.80 m. (360 feet 3 inches); cathedral tower at Magdeburg, 103.60 m. (339 feet 11 inches); tower of the new Votive Church at Vienna, 96 m. (314 feet 11 inches); tower of the Rathhaus at Berlin, 88 m. (288 feet 8 inches); tower of Notre Dame, at Paris, 71 m. (232 feet 11 inches)."

SOME interesting observations have lately been made on the influence of forests on rainfall, in the French School of Forestry, at Nancy. The results of these observations, made during the past six years, are summed up by the sub-director of the school as follows: (1) Forests increase the quantity of meteoric waters which fall on the ground, and thus favor the growth of springs and of underground waters. (2) In a forest region the ground receives as much and more water under cover of the trees than the uncovered ground of regions with little or no wood. (3) The cover of the trees of a forest diminishes to a large degree the evaporation of the water received by the ground, and thus contributes to the maintenance of the moisture of the latter and to the regularity of the flow of water sources. (4) The temperature in a forest is much less unequal than in the open, although, on the whole, it may be a little lower; but the minima are there constantly higher, and the maxima lower, than in regions not covered with wood.

JAPANESE industry is turning to channels well-known elsewhere. The paper mill at Kobe, Japan, belonging to Messrs. Walsh, Hall & Co., is—the *Times* says—working night and day, and turning out large quantities of paper, for which there is a ready sale in Japan and China. At Kobe also are the ironworks of E. C. Kint & Co., which are in full swing, making and repairing the small passage boats that are so numerous on the Japanese coast. A new line of steamers has been inaugurated between Yokohama and Hong Kong by the Japanese company of Mitsu-Bichi, each steamer calling at Kobe. At Sendji a new cloth factory has been started by the Government; but as the native supply of wool is but small, the raw material will have to come from Australia. Commercial civilization has, indeed, gone so far in Japan as to have produced a large issue of forged notes, supposed to have been executed in Germany, and set afloat in Japan through the connivance of Government officials there.

A CONTEMPORY says that writing ink may be prevented from rusting metallic pens by placing broken pieces of steel pens, or any small pieces of iron not rusted, in the bottle in which the ink is kept. The corrosive action of the acid contained in the ink will be expended on the iron introduced.

THE magnesian limestone or dolomite from Bolsover—with which the Houses of Parliament are built, and which has proved a valueless stone for building near the sea or in large towns, on a ccount of its affinity for hydrochloric and sulphuric acids—contains: Silica, 3.6 per cent.; carbonate of lime, 51.1 per cent.; carbonate of magnesia, 40.2 per cent.; iron alumina, 1.8; and water—and loss in analyzing —3.3 per cent.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXV.—MARCH, 1880.—VOL. XXII.

DWELLING HOUSES: THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS.

By Prof. W. H. CORFIELD, M. A., M. D. (Oxon).

From "Journal of the Society of Arts."

I.

SITUATION AND CONSTRUCTION OF HOUSES.

It is only necessary for me to make a few introductory remarks about climate. Although few persons can choose what part of the world they will live in, a considerable number are able to decide in what part of the country they will reside. Other things being equal, the nearer a place is to the sea, the more equable is the climate, and the further inland the place is, the more is the climate one of extremes; so that those who wish for a moist, equable climate, with warm winters and warm nights, will choose a place by the seaside; while those who wish for a more bracing atmosphere will go further inland. In England, too, there is considerable difference, as is well-known, between the climate at various parts of the seaboard. Thus, the western coast, being exposed to the winds which pass over the Atlantic, and to the action of the moist, warm air which passes over the course of the Gulf Stream, has a warm, moist atmosphere, and a heavy rainfall; while the eastern coast, which is swept by winds that have passed across Siberia and Russia, and have only the narrow strip of German Ocean to pass over before they reach our coast, has a dry, bleak, and comparatively cold climate.

For the same reason, too, the exposition of a house, or the way in which it faces, is a matter of great importance in this climate, as is well-known; a southern exposition, for example, being warm and genial, whilst an eastern one is just the reverse.

In the neighborhood of forests, the air is damp during a great part of the year, from the enormous amount of evaporation that takes place from the leaves of the trees, and Humbolt tells us that the large forests on the banks of the Amazon are perpetually covered with mist. Other things being equal, a bare, open country is drier and hotter than a well-wooded one.

I will divide the soils, for sanitary purposes, into two kinds—pervious and impervious; those that allow water to pass freely through them, and those that do not. Pervious soils are such as gravel, sand, and the less compact and softer limestone, which allow water to pass through their interstices, and chalk, in which the water, for the most part, travels through the fissures; and the typical impervious ones, such as the various clays, mostly named from the localities where they are best known, as the London clay, Oxford clay, Kimmeridge, clay. Most of the metamorphic rocks and the hard limestones are non-porous, but have a multitude of crevices, through which the water finds its way. In the former case, the water which falls on the surface passes readily through the soil, until it comes to some impervious stratum below, over which surface it passes, until it either finds outlet at the surface of the ground where the impervious stratum crops out, or until it reaches the nearest watercourse, so that above the impervious layer, which has arrested its progress through the rocks, there is a stratum of water of a depth which will vary with a variety of circumstances—a stratum which can be reached from the surface of the ground by digging wells down to it. This water we call the "subsoil" water, or the ground water (*grundwasser*). In some instances, the impervious stratum just spoken of is placed in such a manner as to prevent the escape of the subsoil water at all, in which case the soil is said to be water-logged. The water which falls on the impervious soils, on the other hand, does not sink into the ground, but remains on the surface, or runs off if there be a suitable incline, and so such soils are necessarily damp. The diseases that are prevalent upon the pervious soils are enteric (typhoid) fever and cholera; during epidemics of that disease—diseases, in fact—the poisons are chiefly communicated by means of drinking water; and the readiness with which the subsoil water just mentioned can be contaminated by the percolation into it of foul matters from the refuse of habitations, combined with the fact that people who live on such soils, as a rule, drink water from wells dug in them, no doubt accounts for the prevalence of those diseases.

On impervious, damp soils, on the other hand, consumption, the great plague of our climate, which kills more than half as many people as all the communicable fevers put together, is prevalent, and so are lung diseases of various kinds—rheumatism, and, under special circumstances, ague. It has been clearly shown that dampness of the soil under the houses is one of the great factors in the production of consumption. Dr. George Buchanan (see 9th report of the Medical Officer of the Privy Council) demonstrated that in every instance where the level of the subsoil water in a town has been lowered, that is to say, where the distances between the basements of the houses and the level of the water in the soil had been made greater, the death rate from consumption had decreased—in one instance to the extent of not less than 50 per cent., so that there can be no question that it is extremely important for everyone who can to live upon a dry soil. Where, then, the soil is not pervious to a considerable depth below the basements of the houses, so that the level of the ground-water comes within a few feet of them, or where the soil, being itself pervious, is naturally water-logged, or in the so-called impervious soils, which are, of course, all pervious to some extent, it is necessary to provide mains whereby the level of the water shall be kept below a certain minimum depth from the foundations of the houses. This is done by drainage, and by a drain I mean a pipe or channel that is intended to remove the water from the soil. It must, therefore, be a pipe into which the water can get—that is to say, it must be pervious to water. The object of drains, then, is twofold, to carry off the surface water, and to prevent the subsoil water rising above a certain height, for as soon as it rises to the level of the drains it finds its way into them, and is carried away to the outfall at a lower point.

Drains may, therefore, be made of stones placed together without cement, as was the case with the Cloaca Maxima, the great drain which was constructed by the second king of Rome to dry the ground around the Forum; or of brickwork, with or without mortar; or, as is very commonly the case, of pervious agricultural tiles. The surface gutters must also be mentioned in connection with the drains, and they are, of course, especially necessary on impervious soils. The ultimate destination of the drains is into the watercourses, streams, rivers, &c.

So much for natural soils; but, especially in the neighborhood of most of our large towns, many of the houses are built upon artificial soil, or "made ground" as it is called. This made ground consists of the refuse of dust-bins, ash-pits, midden-heaps, and the like, which is shot at some place where the ground requires to be raised. It is very undesirable that houses should be built on any such made ground, at any rate for a considerable period. There is no doubt, however, that, after some time, the action of the air and water in the soil causes a slow decomposition of the organic matters in it, and renders it less objectionable as a site for building purposes. Nevertheless, no one would choose to live in a house built upon "made soil" if he could help it.

The proximity of buildings is the next matter to be considered. It is important that houses should not be too near together, as otherwise both light and ventilation are interfered with, and it is now a regulation in the metropolis that a new street shall be at least as wide as the houses on either side of it are high, and that no new street shall be less than forty feet wide.

Having determined the site on which to build, we come next to the foundations. These should not be on made ground, nor on purely vegetable soil, as peat, humus, &c. Their depth is a matter which it is the architect's province to determine, and depends upon various circumstances, such as the weight they have to support. The material used must be the best concrete. The inferior kinds, made with too little lime or cement, crumble away, allow damp air to pass through them, and make the house unwholesome, besides endangering the structure. It is important to remark here that a house should not be built, or even its foundations laid, in frosty weather, for the work will not hold when a thaw sets in.

Basement.—The covering of the ground with some impervious material is imperative, in order that the moist air from the soil may be prevented from rising into the house. In the case of made soils, the covering of the ground should extend for some distance round the house. This covering is best made of concrete some inches thick, and should be used in all cases, whether there are any underground rooms or not. Such underground rooms or basement floor should only be used as cellars—not as living rooms—and should always be arched. The concrete floor may be covered with asphalte, tiles or York paving, but wooden floors should never be used below the ground level. The walls of the house, below the level of the ground and a little above it, should be made with exceptionally good materials, and set in cement, so as to be as impervious as possible to damp. This is a matter that is very frequently lost sight of, and the walls below the level of the ground are frequently made of the worst possible materials. Being hidden from sight, it is often considered that the best materials need not be used for them. It is advisable to have a damp course in the walls all round the house, at a little distance above the ground level, whether the site be a damp one or not. This damp course may be made of asphalte, stoneware, or slate set in cement. Cement alone cannot be depended on. If such a course is not placed in the wall, moisture will rise up through the bricks by capillary attraction, and make the walls of the house damp, rendering the house itself unwholesome. The inner side of the walls in the basement floor may be advantageously made of glazed bricks or of hard black Staffordshire bricks, but no covering of any kind whatever should be placed on those walls. The money should be spent on good construction, and not on covering up bad materials. There should be a dry area all round the walls of the house outside, starting from the concrete foundations. Its width is a matter of little importance, as it is only required to ensure dryness of the walls below the level of the ground, and the ventilation of the cellars in the basement, unless, indeed, the basement rooms are inhabited, in which case, at any rate, the regulations of the Public Health Act must be complied with. This area must have proper connections with the land drains to allow of the removal of the surface water. The materials used for building the walls of the house depend upon the locality. They may be bricks, stone of various kinds (the choice of which must be left to the discretion of the architect), and, in some parts of the country, flint. Bricks stand fire better than anything else, for the simple reason that they have been already burned.

This fact was remarkably shown in the great fire at Chicago, where the brick houses remained comparatively intact, while the granite ones were utterly destroyed. In any case the materials should be set in mortar or cement, and in wet and exposed positions the walls should be double or "hollow" walls, as they are technically termed. Occasionally, in such positions they should even be slated on the outside, or covered with glazed tiles. Walls are sometimes made of concrete, a very ancient plan, and not modern, as is commonly supposed. The Romans frequently used concrete walls in their aqueduct bridges and other constructions. The cement used was of extraordinary hardness, and has, I believe, never been surpassed, even if equaled, in later times. It might be called the "cement of the Romans," as the term "Roman cement" is now commonly applied to a very inferior article. In making concrete columns, the Romans adopted the practice of inserting layers of their flat bricks, which we should perhaps call tiles, at intervals, and they faced the surface with stones, generally disposed after the fashion known as *opus reticulatum.* This consisted in placing small cubical blocks of stone against the surface of the concrete, so that the sides of the exposed faces were not vertical and horizontal, but the diagonals were, thus giving the appearance of network, or of a chess-board set up on one corner. These devices assisted greatly in protecting the structure from the weather, and from rough usage. Such walls may also be very well faced with tiles of various kinds.

The chimney flues should be as straight as possible. They should be separate from one another—a matter very often not attended to—and they are better lined with pipes, as these are much more easily cleaned; an up-draught is more readily established in them, and they completely disconnect the flue from the structure of the house, and so help to prevent destruction by fire.

It is important that the chimneys should be higher than the surrounding buildings, so that the wind may pass freely over them, and that they may not be sheltered from its action in any direction whatever. If this is not the case, there will be a down draught in the chimneys when the wind is in a certain direction, and the more the chimneys are sheltered by high buildings the more chances there are of down-draughts in them. If necessary, an iron or zinc pipe called a "tall-boy," may be placed on the top of the brickwork, to increase the length of the flue. This is sometimes even carried up adjoining buildings, and is, as a general rule, better without a cowl of any kind on the top of it, as will be further explained in the next lecture.

Flooring.—Fire-proof floors are most desirable. They may be made of concrete or brick arches between iron girders, in which case there is no space between the flooring of one room and the ceiling of the room below. When timber is used, it should be dry and well-seasoned, with sound boarding, to ensure a separation between the rooms, and to prevent either water leaking from the floor to the ceiling below, or air passing from the room below to that above. Good flooring evidently serves to protect the ceilings of rooms below. Where there is space between the flooring and the ceiling, and still more especially where a wooden flooring is placed over a concrete or other foundation laid on the ground, it is necessary to provide for ventilation of the space below the flooring. This is usually done by placing a perforated iron grating, instead of a brick, here and there, in the outer walls, so that air can pass freely in or out below the floors. For this purpose bricks, such as those exhibited, with conical holes through them, would no doubt be found very useful.

The Roof.—This may be constructed either of fire-proof materials, or of timber, and in either case may be covered with slates or tiles, or may be thatched; copper or corrugated iron are also used. Sometimes zinc is used on account of its cheapness. It is not a good material, as it does not last long. Lead is largely used, especially upon flat roofs, and is valuable an account of its lasting properties. Where there are eaves, it is important that they should not drip on to the walls, but project, so as to throw the water off. Cornices and all projections should be constructed so as to throw off the rain, or it will run down the walls. If this is not done, the walls will be continually damp and dirty. Rain-water gutters may be made of lead or iron. They must have a sufficient fall, and shoot directly into the heads of the rain-water pipes. They should be wide enough inside to stand in, so that the snow may be cleared out. If this is not done, it will accumulate, blocking up the channel, and when the thaw comes the melted snow will work its way through the tiles or slates of the roof, and injure the ceilings below.* Rain-water gutters should not be carried through the house from one side to the other, and especially not through bedrooms. Nor should they be carried, as is sometimes done, round the house inside the walls, and through the rooms. A more or less disagreeable smell is frequently noticed in rooms through which rain-water gutters pass. The rain-water pipes should also be outside the house. They should be of iron, well jointed. Galvanized iron ones are preferable; they are only a little more expensive and last much longer. They should either discharge into rain-water tanks, which must be well ventilated, or on to the surface of the ground or area round the house. They should not be connected directly with the drains or sewers. Neither should they be placed with their hoppers or heads just below the bedroom windows, especially if they discharge into a tank. Large and high houses, especially if standing alone, require to be provided with lightning conductors. Copper ones are better than iron, and need not be so thick. They must be insulated from the walls of the house by suitable rings of some non-conducting material, and end in some moist place in the soil. In the case of an isolated house it is also a good plan to have a weathercock on the roof, and connect that with a registering apparatus in the hall. An anemometer is also useful.

Thus far about the construction of the building itself. We now come to the finishing off inside. The floors should be covered with boarding—oak bees-waxed being the best, or deal, stained and varnished, may also be used. The joints are better tongued. Parquet flooring, made of teak, may be placed over the whole of the surface, the object being to ensure, as far as possible, a uniform and impervious surface, without cracks or badly made joints, in which dust can accumulate. This is especially important. Either of these plans is better than the common one of covering the whole floor with a carpet or drugget. When these are used, a border of stained and varnished or polished boards, or of parquet flooring, should be left all round the room. This has the advantage that dust does not accumulate so readily in the corners, which are more easily swept and cleaned, and the carpet can be taken up at any time to be beaten, without moving the furniture which is against the walls. The skirting boards of wooden floors should be let into a groove in the floor. This will serve to prevent draughts coming through, and dust accumulating in the apertures, which are invariably formed by the shrinking of the joints and the skirting. Some floors, such as those of halls, greenhouses, &c., are best tiled.

Wall Coverings.—These, like the floors, are better made of impervious materials which can be washed. Tiles form an admirable wall covering, and are, moreover, a permanent decoration. Various kinds of plastering, with the surface painted, form a cheap and effective wall covering. Paint containing lead should, of course, not be used, but the silicate, or the indestructible paints, and zinc white should be used instead of white lead. Paper as a covering for walls has the disadvantage that, as a rule, it cannot be washed, and that the dust collects on it. For this reason, after a case of infectious disease, it is necessary as a general rule to strip the paper off the walls, whereas a painted or tiled wall can be washed. Many papers, too, are colored with arsenical paints, and seriously affect the health of the persons living in the rooms, the walls of which are covered with them. For a considerable amount of information on this subject I would refer to a little book which has just appeared, entitled "Our Domestic Poisons," by Mr. Henry Carr.

Ceilings.—For these plastering is in most general use. It is better painted than distempered. Whitewashing, however, answers very well, and can be repeated as often as necessary. Paper

* The remark as to the width of gutters does not apply to eaves-gutters.

should not be used for covering ceilings. If they are of wood it should be paneled, or the joints will let the dust through. The wood work generally throughout the house should be stained and varnished, polished, or painted; and generally I may sum up the principles to be followed in finishing off the inside of a house by saying, that the materials should be, as far as possible, impervious, and the surface smooth and uniform, and so disposed as to be easily cleaned, and not to collect the dust.

VENTILATION, LIGHTING, AND WARMING.

The air in our houses is rendered impure in various ways, but chiefly by our respiration, and by the products of combustion that are allowed to escape into it from lights and fires. The air that we expire contains a certain quantity of foul, or putrescent, organic matter. It is charged with moisture, and contains about five per cent. less oxygen and nearly five per cent. more carbonic acid than the air that we inspire. It is neither the diminution of oxygen nor the increase of carbonic acid in the air of rooms that is of the greatest importance to living beings, but the accumulation of foul organic matter and the excess of moisture. It is this which renders such atmospheres stuffy, and not the diminution of oxygen or the increase of carbonic acid, which are so slight as to be of little importance, even in overcrowded rooms. Nevertheless, since the increase in carbonic acid is proportional to the increase in other impurities, and since we can estimate very accurately the amount of carbonic acid in the air, the increase of carbonic acid is taken as an index of the impurity of the atmosphere. The average amount of carbonic acid in the outer air is four parts in ten thousand. Professor De Chaumont found by his experiments that, whenever the amount of carbonic acid in the air of a room exceeded the amount in the outer air by more than two parts per 10,000, the air of the room was not fresh, that is, say, that the foul organic matter in it and the excess of moisture were sufficient to make the room stuffy. Hence, two parts of carbonic acid per 10,000 of air, over and above that in the outer air, are taken as the limit of respiratory impurity. As an adult breathes out, on the average, six cubic feet of carbonic acid in ten hours, it is clear that, in order that the air of the room in which he is may be kept fresh, he must have 30,000 cubic feet of air in the ten hours, or 3,000 per hour. In this climate we cannot change the air of a room more than three or four times per hour without causing draught, and so each person ought to have from a thousand to 750 cubic feet of space, the air of which should be changed three or four times per hour respectively. The way in which this space is arranged is also a matter of some importance. For instance, the air above a certain height is of little use for purposes of ventilation, if combined with too small a floor space. To take an extreme case—a man standing on a square foot of ground, with walls 3,000 feet high all round him, would be in 3,000 cubic feet of space; but it is quite obvious that he could not live in it. But, even without any enclosure at all, and without any limit as to height, it is not difficult to conceive a place overcrowded. For instance, all the inhabitants in the world, men, women, and children, could stand upon the Isle of Wight; but it is quite certain that they could not live there, even if it were only for the want of air. So it is usual, in estimating cubic space, to disregard the height above eleven or twelve feet. It is also obviously of importance that the floor space should be properly distributed; but, about this, so far as dwelling-houses are concerned, there is no need to enter into particulars. We are not able to insist on anything like 1,000 or 750 cubic feet of space in all instances, and amounts varying down to as low as 300 cubic feet per individual are adopted. In the case of a family living in one room, which is so small as to afford less than 300 cubic feet per individual, it is usual to consider that the limit of overcrowding which should be allowed by law has been reached. We cannot have, as a general rule, rooms so large that the air does not require changing while we are in them. Thus, for instance, a person in a bedroom for seven hours consecutively requires about 21,000 cubic feet of air if the atmosphere is to be kept fresh. Supposing him to have this without change of air, he would require a room, say, 70 feet long by 30 wide and 10 high. This makes it quite clear that in rooms such as we have there must be a change of air.

In studying ventilation from a practical point of view, the chief agents that we have to consider are the winds, and movements produced in the air by variations in its density, usually brought about by variations in its temperature; the property of the diffusion of gases by means of which the air is brought to a uniform composition when the temperature is the same throughout, being one which, practically speaking, does not affect the question much. With artificial methods of ventilation, in which the air is forced in a certain direction by machinery, we have little to do, as few of them are suitable for use in dwelling houses. The wind, as an agent of ventilation, is powerful, but its disadvantage is that its action is irregular. When all windows and doors can be opened, a current of air which may be imperceptible, is quite sufficient to change the air of a house in a very short time, and houses that have windows on both sides are for this reason much more healthy than houses built back to back, which can never have through ventilation. This is the direct action of the wind, which may generally be utilized in large rooms with windows on opposite sides, like schoolrooms, by opening that which is nearest to the direction from which the wind comes, a little way at the top, and also opening the one which is diagonally opposite to it at the top a little further than the first one. The direct action of the wind has also been utilized for ventilating large houses by Silvester's plan, which consists in having a large cowl, that always faces the wind, at the top of a pipe leading down into cellars in the basement of the house, where the air can be warmed by stoves, and allowed to ascend into the house. By this plan the holds of ships are frequently ventilated. But the aspirating action of the wind is, perhaps, of greater importance. When the wind blows over the top of a chimney, or over a ventilating pipe, it causes a diminution of pressure of the column of air in the chimney or ventilator, and so produces an up-current, upon precisely the same principle that little bottles made for distributing scent about apartments act. For this reason, it is, as was hinted in the last lecture, important that chimneys should be higher than the surrounding buildings, so that any wind that blows may cause or increase an up-draught in them. In this way not only is smoke prevented from ascending into the rooms, but the amount of air carried through rooms up the chimneys is increased, and the ventilation of the house improved. There being, then, in every house, and frequently in every room, a shaft—whether sufficient or not, we will consider by-and-bye—for the escape of air, it becomes of the first importance for us to consider the means by which air may be admitted into our houses and into our rooms. In summer, and whenever the air is as warm outside the house as inside of it, there is no difficulty about this. We have only to open the windows—wind-doors, remembering the proverb that "Windows were made to open and doors to shut"—on both sides of the house, and the air is generally changed fast enough, but it is in winter, when the air is colder outside the house than inside, that the difficulties arise, and so in speaking of ventilation I shall always assume that the air outside the house is colder, and therefore heavier, and exercises greater pressure than the air inside it. This being the case, it follows that if we open a window, or make an aperture through a wall into the outer air, or through the wall of a room into a passage, or staircase, in which the air is colder than it is in the room, air will come in. In fact, a room under these conditions may be looked upon as if it had water outside of it, and it is quite apparent that, in such a case, if you bored a hole through the wall into the water on the other side, water would come in, and the air of the room would escape by the chimney. This is precisely what happens with the cold air outside. If no special opening is provided through which the cold air can come into a room, it enters by such openings as there are; by the apertures between the sashes of the windows, by the—perhaps fortunately—badly fitting doors, crevices in the floors, walls and cupboards, through the walls themselves, as has been shown by Pettenkofer, and sometimes down the chimney. If, then, air will come in through an aperture placed in any position, it becomes necessary to consider where apertures should be placed, and what precautions are necessary with regard to them. Theoretically, the admission of pure air should be at the lowest part of the room, and the extraction of the vitiated air, which is warm, at the upper part of the room; but practically the outer air cannot be admitted without certain precautions at the lower part of the room by mere apertures, as everybody knows who has been accustomed to sit in a room when a draught comes under the door. On the other hand, if an aperture is made into the outer air through a wall at a few feet from the floor, the air enters in a cold straight current for some distance into the room. If the aperture be higher up, it comes in and falls, just as water would do, on to people's heads, somewhere about the middle of the room. So it is quite clear that certain precautions are necessary in the admission of air so as to prevent draughts. Since we have, or ought to have, windows in all rooms, it will be convenient to consider, first, the ways in which they may be utilized for the admission of air. We cannot simply open a sash window at the top or bottom in cold weather without feeling a draught, but there are several ways in which this difficulty may be got over. The simplest is by placing a board of wood underneath the lower sash, as suggested by Dr. Hinckes Bird, whose original model I have here. This board is sometimes now made with a hinge in the middle, so that it can be got in and out more easily; or the board, instead of being placed under the lower sash, may be placed across, from side to side, in front of the lower part of the lower sash, so that the lower sash may be opened to a certain height without any air coming in below it. These boards may be covered with green baize, or some other suitable material, so as more perfectly to prevent the entrance of the air at the lower part of the window. In either case, the bars of the sashes at the middle of the window are no longer in contact, and air comes in at the middle of the window, between the two sashes, taking an upward direction, in the form of a fountain, and producing no draught. This shows us the direction in which cold air ought to be admitted into a room—after the fashion of a fountain, in which it can be readily obtained, owing to its greater pressure, and not after the fashion of a waterfall.

This simple plan, which I recommend very strongly for adoption, has two disadvantages, one that nervous people always fancy there is a draught if they see anything like a window open, and the other a much more practical one, but one that is common to most forms of ventilation that are inexpensive—that a certain quantity of blacks enter. These conditions are, to a certain extent, got over by the plan suggested by several inventors—of boring holes through, or cutting pieces out of the lower bar of the upper sash. Such holes are not seen; and the air comes through them in a vertical direction into the room. They can also be fitted with little boxes containing cotton wool, through which the air will be filtered and deprived of soot, etc. This, of course, very considerably diminishes the amount of air that enters, and the cutting also weakens the framework of the window. I may here mention Currall's window ventilator, which consists of a metal plate fastened along the lower bar of the lower sash, and parallel to it, with an opening below the sash for the admission of air, which is thus deflected into a vertical direction by the metal bar. Here will be also a convenient place to mention the automatic sash fastener patented by Messrs Tonks & Sons, by means of which the window is securely fastened when opened to the extent of three or four inches, either at the top or bottom, so that the window can be left open without any one outside being able to open it further. This can also, obviously, be combined with the window block placed underneath the lower sash, so that air can be admitted in the proper direction, and the window still be securely fastened.

Louvred ventilators may also be used in a variety of ways in connection with windows. Where there are venetian blinds, it is only necessary to open the top sash, pull the venetian blinds down in front of the opening, and place the louvres so that they give the entering air an upward direction. Glass louvres fixed in a metal frame work, may also be used, a pane of the window being taken out and one of these ventilators substituted for it. The louvres can be opened and shut by means of a string, and they are so fixed that it is impossible to break them by doing so. They are generally fixed instead of one of the top panes of the upper sash. It is better to place them lower down in the upper sash; and this is true of all inlets of air. If they are too high up, the air being admitted in an upward direction, impinges against the ceiling, rebounds into the room, and produces a draught. The metal frame work of these ventilators requires oiling and attending to, or it will get rusty. In some places fixed louvres of wood, or still better, of strong glass, may be fixed with advantage, or swinging windows with sashes hung on centers may be used, as, for example, in water closets; and these, where it is advisable, may be prevented from being closed by a means of a small wedge of wood screwed to the frame work. The blind so often placed across the lower part of a window may also advantageously be used as a ventilator, or, where no blind is required, a glass one may be used, this being made to swing forward on its lower edge, so as to give the entering air an upward di rection when the lower sash is opened, as in the model here shown, which was presented by Messrs. Howard to the Parkes Museum. Where very large quantities of air require to be admitted, one or more sashes of a window may be made to swing forward in this way, as is now done in the large hall of Willis's Rooms. Near to all windows, in the cold weather, the air of the room is colder than at other parts of the room. This may be obviated, when considered advisable, by the employment of double windows, the layer of air between the two windows preventing, to a very considerable extent, the cooling of the air inside the room. It is not advisable to have double panes of glass in the same sash, as the moisture between them will render them more or less opaque in certain states of the weather. With double windows, air may be admitted by opening the outer one at the bottom and the inner one at the top. Where French casement windows are used, as they sometimes are unadvisedly in this climate, ventilation may be provided by having a louvred opening above the casements of the window, or by making a glass pane or panes capable of being swung forward on the lower edge. Lastly, Cooper's ventilator is largely used for windows, and also in the glass panes over street doors. It consists of a circular disk of glass, with five holes in it, placed in front of a pane of glass with five similar holes, and working on an ivory pivot at its center. It can be moved so that the holes in it are opposite to those in the window pane, when air will, of course, come in; or, so that they are opposite to the places between the holes in the panes, when the air will be prevented from entering. It is obvious that the air is not admitted in an upward direction, but the disadvantage of this is partly counterbalanced by the fact that it is admitted in five small streams, and not in one large one, so that there is less probability of a draught.

The air may also be admitted through apertures made in the walls or doors. The simplest way to do this is to make a hole through the wall, and fasten a piece of board in front of it in a sloping manner, so as to give the air an upward direction. It is better to put "cheeks," as they are called, on the sides, for they serve not only to attach the sloping board to the wall, but to prevent the air from falling out sideways into the room. This ventilator may be hidden by hanging a picture in front of it, and will cause no draught. I may state here that it is better in a large room to have two or more small ventilators of any kind whatever than one large one, and that no single inlet opening should be larger than a square foot. Openings of half that size are preferable. It is calculated that there should be 24 square inches of opening per head, so that a square foot would be sufficient for six persons. In such an opening as has been described, wooden or glass louvres may be placed. The same end may be attained by making one of the upper panels of a door to open forwards with hinges to a certain distance; or, even in some instances, by fixing it in this position. An obvious disadvantage, and one which always has to be considered in making openings through walls and doors is, that conversation which goes on in the room can be heard in the passage outside. Sherringham's valve is a modification of this plan, and can be fitted either into an outer wall or into one between the room and the passage or hall. It consists, as you see, of a metal box to fit into the hole in the wall, with a heavy metal flap, which can swing forwards, and is exactly balanced by a weight at the end of a string passing over a pulley, the weight acting as a handle, by means of which the ventilator can be opened or shut or kept at any desired position. What has been said before applies to these ventilators. They should not be placed too near the ceiling, and this is the mistake that is generally made in fixing them. Stevens' drawer ventilator may also be mentioned here. The name almost describes it. It resembles a drawer, which is pulled out of the wall for a certain distance, and allows air to come into the room vertically in several streams between metal plates placed inside the drawer. Jennings' "Inlet," which is in use in the barracks, consists of an opening through an outer wall, into a chamber in which dust, etc., is deposited, and thence between louvres into the room. Here I may mention that it is sometimes advised to place perforated zinc or wire gauze outside the entrance to the ventilators, so as to prevent dust, etc., coming into the room. This is not advisable, as the apertures get clogged up, and the entrance of air is much impeded. It is better to have an iron grating which will prevent birds entering, and to employ other methods for preventing the entrance of dust, soot, etc. Where this is considered necessary, the plan of passing air through cotton wool, which must be frequently changed, may be adopted. Currall's ventilator for admitting air through the door is sometimes useful. It resembles his window ventilator almost exactly; a long slit is cut through the door, a perforated metal plate placed outside, and a flat plate fixed parallel to the door inside and in front of the slit, thus giving the air as it comes into the room an upward direction. An admirable plan for the admission of air into rooms is by means of vertical tubes—an old system, but one which has been brought into prominence of late years by Mr. Tobin. A horizontal aperture is made in the wall into the outer air just above the floor, and then a vertical pipe carried against the wall to a height of from four to five feet. The cold air is thus made to ascend like a fountain into the room. It does so in a compact column, which only perceptibly spreads after it has got some height above the mouth of the tube. It then mixes with warm air at the top of the room, producing no draught at all. In spite of the vertical height through which air has to pass before it emerges into the room, a considerable amount of soot and dust of various kinds is brought into the room. This may be obviated by placing a little cotton wool in the interior of the tube. This, however, although a very efficient plan, has the serious disadvantage of impeding the current of air. A better plan is the one patented by the Sanitary Engineering and Ventilating Company; a tray containing water is placed in the horizontal aperture in the wall, the entering air being deflected on to the surface of the water by metal plates. The greater part of the dust is thus arrested by the water, which can be changed as often as necessary. In warm weather ice may be placed in the trays. Another plan is to place in a vertical tube a long muslin bag with the pointed end upwards, and kept in shape by wire rings. This provides a large filtering area, and offers very little resistance to the passage of air. The bag may be taken out and cleansed as often as necessary.

Several contrivances have been devised for the admission of air close to the floor, just behind a perforated skirting board. Among these are Ellison's conical ventilator, shown in the last lecture, and Stevens' skirting board ventilator, in which metal cups are placed in front of the inlet openings, and so distribute the air that no draught is felt. I think, however, that it is only advisable to admit warmed air at a low level into rooms, but there is no reason why such openings should not be made high up in the rooms—behind cornices, for example. Pritchett's paving, made of agricultural pipes, may also be used for making walls and partitions, and is obviously applicable for ventilation purposes, whether used as inlet or outlet.

We now come to speak of exit shafts and valves. The first and most important of these is the chimney, about which I have already spoken. I need only add here that it is advisable to do without the use of cowls upon chimneys wherever it is possible. If the chimney can be made high enough it will not require a cowl, and if it cannot, a simple conical cap is generally sufficient to prevent down draughts. There is no doubt, however, that Boyle's fixed chimney cowl for preventing down draught not only does so, but produces an up draught in the chimney when the wind blows down upon it, as I can readily show you by an experiment with the model I have here. A small piece of wool is made to ascend in a glass tube by blowing vertically down upon the fixed cowl placed upon the top of it. Of revolving cowls for chimneys, the common lobster-backed cowl is probably the best. Whilst speaking of cowls, I may as well mention that a variety of cowls, some of which I have here, have been invented with the object of increasing the up draught in exit shafts of various kinds, some are fixed, as Boyle's, Buchan's, and Lloyd's, and some revolving, as Scott, Adie & Co's., Howarth's, Stidder's, Banner's, Stevens', and the one invented by Mr. Boyle, but discarded by him some years ago. Whether any of these cowls increase the up current in exit shafts is a matter which is still under investigation, but I can show you, quite easily, that the common rough experiment, by means of which they are supposed to do so, is entirely fallacious. Cotton wool is drawn up a tube at least as easily by blowing across it in a slanting direction as by blowing through a cowl placed on the top of it. The fixed cowls have the advantage that they cannot get out of order. The revolving cowls have the disadvantage which is common to all apparatus with moving parts, that they are certain to get out of order some day or other. Whether they increase up draughts or not, there is no doubt that most of them prevent down draughts, and, like any other cover, prevent the entrance of rain.

Openings are sometimes made high up in the room into the chimney flue and protected by valves, the best known of which is Arnott's valve, which consists of a light metal flap, swinging inside a metal frame work in such a way that it can open towards the chimney flue, but not towards the room. Any pressure of air from the room towards the flue will, therefore, open it and allow the air to escape from the room into the flue. Pressure of air the other way will shut it. The disadvantages of this ventilator are that it makes an irregular noise, although this has been, to a considerable extent, obviated by the india-rubber padding with which it is now fitted. It also occasionally admits a little soot, and, of course, air at the same time, from the flue into the room. Boyle's chimney ventilator, made by Messrs. Comyn, Ching & Co., is a modification of this. Instead of the light metal flaps, there are a number of small talc flaps. These make little or no noise, but they are liable to be opened by a current of air in the chimney. It is obviously, it seems to me, at variance with sound sanitary principles to make openings from the interior of the room into the chimney flues, and then to trust to valves for preventing the air of the flue from coming in. A far better plan is to have shafts placed by the side of the flues, and this, of course, is better done when the houses are built. The easiest and most satisfactory way of doing it is by means of air and smoke flues combined, in which the air flues are molded in the same piece of fire-clay as the smoke flue itself. These air flues can be connected with the upper parts of the rooms, and up draughts will be inevitably caused, as the air in them will be considerably heated on account of its immediate contact with the outer side of the flue. Such shafts can only serve as inlets when the flues are cold, and so it is advisable to use them especially with flues that are always hot—as, for instance, that of the kitchen chimney—and it is desirable, wherever it can be done, to connect the kitchen with a different air-shaft from the other rooms, or it is possible that air from the kitchen may get into some of the other rooms of the house.

Of exit ventilators not connected with the chimney flues, I may mention Mackinnell's, which also provides an inlet for air as well, and which is very useful in little rooms, closets, etc., having no rooms over them. It consists of two tubes, one inside the other, passing through the ceiling into the outer air. The inner one is larger than the outer one, and projects above it outside and below it an inch or so into the room. At its lower end a circular rim is attached horizontally parallel to the ceiling. The outer air enters between these two tubes, and is deflected by the rim just mentioned along the ceiling, so that it does not fall straight into the room. The vitiated hot air passes out by the inner tube, the action of which is, of course, considerably increased if a gas burner or other light be placed beneath it. It is upon this principle that the lamps for lighting railway carriages are made, the reflector answering the purpose of the rim round the end of the inner tube, and the air to supply the lamp coming in between the reflector and the glass shade, while the products of combustion escape through the pipe leading from the middle of the reflector, and immedietely over the flame. Of course Mackinnell's ventilator requires a cover to keep out the rain, and it is necessary, in fact, to have a double cover, so that the heated air which escapes by the inner tube shall not be carried back into the room by the entering air. Tossel's ventilator is a variety of this, with a cover by means of which the action of the wind is able to be taken advantage of. The same inventor has also contrived one which can be used between the ceiling of one room and the floor of the room above, provided that this space can be well ventilated.

This brings us naturally to say a little about lighting. Candles, lamps, and gas, help to render the air impure. It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men, or even more. This is why it is commonly considered that gas is more injurious than lamps or candles, and so it is when the quantities of light are not compared, but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles. If, in the dining-room, instead of using five or six gas burners, as we too often do without any provision for the escape of the products of combustion, we used 40 or 50 sperm candles instead of 6 or 8, we should have a fairer comparison between gas and candles.

I have no time to enter into a discussion of the relative merits of various kinds of candles and lamps, but with regard to gas I would say that, considering the fact I have just stated, it is always advisable to provide a means of escape for the products of combustion immediately over the gas burners. By this, not only may these products be carried away, but, with a little contrivance, heated air may be drawn out of the room at the same time, and so an efficient exit shaft provided, in addition to the one found already in the chimney. Very simple contrivances will answer this purpose. A pipe, with a funnel-shaped end, starting from over the gas burner, and carried straight out into the open air, with a proper inlet opening, is all that is required in some instances, as in badly placed closets. For large rooms, the sunlight ventilators are found to answer admirably. They should be provided with a glass shade, placed below them to intercept the glare, and to cut off a large portion of the heat. An elegant contrivance for dwelling-rooms is Benham's ventilating globe light. In this, the products of combustion of the gas pass along a pipe, placed between the ceiling and the floor of the room above, into one of the flues. This pipe, being surrounded by another opening into the ceiling of the room at one end, and into the flue at the other, is guarded at its entrance to the flue by a valve which can be easily shut when the gas is not burning. This double tube, as it passes under the floor of the room above, is covered with a fire-proof material, so that the floor is not affected by it. The joists, where they are notched, have iron bearers put across to support the floor boards above. Air is admitted by another pipe passing through the wall of the house into the external air, and ending also in the ceiling of the room by openings around those of the exit shaft. Thus warm air is introduced into the room at the same time that vitiated air from the upper part of the room, and also the products of combustion of the gas, are carried out of it into the chimney flue.

I may say a few words about some grates and stoves that have been devised with the view of combining ventilation and heating. The first of these is Captain Douglass Galton's grate, in which there is an air chamber placed around the flue, and communicating on one side with the external air, and on the other with the atmosphere of the room by various apertures. The outer air which passes into this chamber is warmed by contact with the heated flue, and issues into the room, thus supplying the room with warmed air, and utilizing a considerable quantity of the heat that would otherwise be lost. There are several other grates, such as the Manchester school grate, made upon this principle, with variations in the arrangement of the inlet apertures, which are placed vertically like Tobin's tubes, etc. It is important in all these contrivances, where the outer air passes through a chamber in which the back of the grate and the flue is placed, that the back of the grate and the commencement of the flue in that chamber should be cast in one piece of metal, so as to have no joint. If there are joints they will become after a time defective, and air from the flue is liable to escape into the chamber round it and be brought back into the room by the entering air. Some slow combustion stoves, as George's "calorigen," have air pipes passing through them, and have the external air warmed on its way through the stove into the room. Iron slow-combustion stoves dry the air too much, and unless they are lined with fire-clay, are apt to become too hot, and to cause an unpleasant smell in the room by the charring of the organic matter in the air. They are much more suitable for warming large buildings, where economy of fuel is an important object, than they are for use in sitting-rooms or offices. It is usual to place a vessel of water on the top of these with the view of obviating, as far as possible, the dryness of the air that they produce. It must be borne in mind that closed slow combustion stoves do not act as ventilators, as the air to supply the fuel—usually coke—is brought by a pipe from outside, and this is another reason why they are not so advantageous as an open fire or a quick combustion stove in dwelling-rooms. In the Thermhydric grate of Mr. Saxon Snell, a small boiler is placed behind the grate, and communicates with a series of iron pipes alongside of it. These are filled with water, which is, of course, kept warm, and air is admitted to the room between these hot water pipes. Thus, it is neither dried nor heated too much. The products of combustion are carried away by a flue, which may be placed under the floor; so that the grate, if required, may stand in the middle or in any other part of the room.

Gas stoves are gradually becoming largely used instead of coal, and, when proper provision is made for the escape of the products of combustion, they are certainly very convenient, and cleanly contrivances. I have no doubt that this will, in the end, be found to be the proper use for gas, and that we shall cease entirely, or almost entirely, to use coal in our houses. By using coal in the way that we do, we lose all the valuable bye-products—the ammonia, the tar, the carbolic acid, aniline dyes, etc., which are derived from the refuse of gas works, and which are worse than useless to us in our fires. Gas may be burned either mixed with air or not. In the first instance, a gas stove or grate filled with pumice-stone or asbestos does not much resemble an ordinary fire, but if the gas be burned unmixed with air it is almost impossible to tell the difference. Generally speaking, it is found necessary, when there are several gas stoves in a house, to have a special supply of gas with larger pipes for them. What the gas companies should do is to lend gas stoves of various kinds, especially cooking stoves, to their customers for a small annual payment, as is done very successfully in Continental cities. It is important that gas cooking stoves should not give an unpleasant smell of unburnt gas as some do. This is not only a waste but a nuisance, as coal gas always contains carbonic oxide (an extremely poisonous substance), and should, therefore, not be allowed to escape into the air, even in the smallest quantity.

I have now to mention an artificial system of ventilation which has been lately introduced by Messrs. Verity Brothers. It consists essentially of a fly-wheel fitted with fans or veins. The wheel is made to revolve by a jet of water directed against it, and supplied from a cistern overhead, the water passing off by a pipe into a cistern below. The apparatus can be fixed either in an inlet opening, and so made to propel air into the apartment through an aperture in the wall placed higher than people's heads, and made in a slanting direction, so that the entering air is shot upwards towards the center of the room; or it can be used as an extractor, by placing it in an exit shaft, and causing it to draw the vitiated air out. The supply of water can be regulated by taps, to the greatest nicety, so that the wheel can be made to revolve at whatever speed is desirable. The entrance pipes are sometimes fitted with a vertical tube containing a box, in which ice can be placed, or a holder for perfume, or any deodorant. For smoking rooms it is found advisable to use the apparatus as an extractor only, and to allow the air to come in by means of Tobin's tubes.

Dwelling-houses are seldom warmed and ventilated by means of hot-water apparatus, and so I do not think it necessary to enter into a description of the plans by which this may be effected. I need only mention Mr. Pritchett's "miniature hot water apparatus," if I may so call it, by means of which a single room may be warmed and ventilated. The water starts from a small boiler, the size of an ordinary kettle, which may be placed on a fire anywhere, or heated by a spirit lamp, and passes through a narrow space between double cylinders, the inner cylinders being used for the admission of fresh air, which is warmed in passing through them, or for the extraction of foul air. The water is made to pass through the extraction cylinders first, while it is hottest, and then through the others and back to the boiler. The cylinders are placed vertically, so that the air is admitted into the room in the proper direction. Other systems of artificial ventilation are suited for large public buildings, but are not adapted for use in dwelling-houses.

For the purpose of these lectures we must assume that it is necessary to have a sufficient supply of water that is fit to drink for all uses. The obvious characters of a good drinking water are that it is clear, transparent and colorless without taste (that is to say, neither salt nor sweet), and without smell, that it has no suspended particles in it, and produces no deposit on standing, and that it is aerated; but a water may possess all these characteristics and yet be unfit to drink, by reason of dissolved matters which cannot be detected except by chemical analysis, but the existence of which may often be suspected from a knowledge of the history of the water. Waters are commonly divided into hard waters and soft waters. Hard waters are those which contain a considerable quantity of mineral salts, especially salts of lime in solution; soft waters those which contain much smaller quantities of these substances. Very hard waters are unfit for domestic purposes. A deposit of mineral matters takes place in the supply pipes, etc., and they get blocked up. Such very hard waters, too, are not desirable either for drinking or for domestic purposes generally. Moderately hard waters appear to be as wholesome as soft waters for drinking purposes. The Registrar-General has shown that the death-rate, in towns supplied with moderately hard water, does not differ sensibly from that of a series of towns supplied with soft water, but in other respects similar in their sanitary arrangements. Nevertheless, animals in their natural state prefer soft water to hard, and those who have the care of horses always give them soft water to drink if possible. An undoubted disadvantage that attends the use of hard water for domestic purposes consists in the enormous waste of soap that it entails. In order to wash with soap, it is necessary to produce lather. Now, the mineral salts in hard water decompose the soap, and form insoluble compounds, so that solution of the soap in water which will form a lather, does not take place until the lime, etc., in the water has been deposited as insoluble lime soap, etc. Thus the more salts of lime and other mineral matters are present in the water, the more soap is wasted before the formation of a lather. This can be easily illustrated by a simple experiment. If we take a sample of distilled water, which contains no mineral matters in solution, and add a certain measure of an alcoholic solution of soap to it—when we shake the bottle in which it is, a lather is immediately produced and remains for some time; but when we take the same quantity of another sample of water, and add the soap solution to it, we find that it requires, in this instance, about twenty times as much of the solution to form a lather. (Experiment shown.) Soft water then, on the whole, must be preferred to hard for domestic purposes, and when the water is very hard it ought to be softened before being distributed. This may be done by Clark's process, which consists in adding milk of lime to the water as long as a precipitate is formed. The *rationale* of this is that most of the hard waters contain considerable quantities of carbonate of lime, which is held in solution in the water by the means of free carbonic acid. The lime added as milk of lime combines with the free carbonic acid, forming more carbonate of lime, which, together with the carbonate previously in solution, is deposited, being almost entirely insoluble in water. As it is deposited, it carries down with it any suspended matters that may be in the water, and so leaves the water clearer and purer. A practical difficulty in the carrying out of this process, arising from the length of time required for the precipitate to subside, has been overcome by a process of filtration devised by Mr. Porter, and known as the "Porter-Clark process." Water, after being distributed, may be softened to a considerable extent on a small scale by boiling, when the carbonic acid gas is thrown off, and the carbonate of lime deposited. It is this which causes the incrustation of boilers. The boiling also helps to purify the water in other ways, and it is a very good plan to use boiled water, either when the water is very hard, or when there is any suspicion of impurity, both for drinking and for domestic purposes generally. It may be aerated by allowing it to fall from a height from one vessel into another. The average quantity of water required in a community is generally put down at from 30 to 35 gallons per head daily. Of these, from 20 to 25 are required for household purposes (including waste), where baths and water closets have to be supplied, and ten or more are necessary for washing the streets, for flushing the sewers, and for trade purposes.

The important sources of water are: (1.) Rain collected directly. This is of course very soft water, and in country places very pure. In towns it is rendered impure by the substances that it washes out of the air, and must be filtered be fore it is used, but it is everywhere an important and valuable source of soft water which is far too much neglected. It ought to be collected and used for domestic purposes, and wherever there is any suspicion as to the quality of the water supplied from other sources, rain water should (especially in the country) be used for drinking. It may be filtered through sand, gravel or charcoal by means of very simple contrivances.

(2.) Water is often obtained from shallow wells dug in the soil, down to a little below the level of the subsoil water. These, of course, drain the soil around for a greater or less distance, and the water in them frequently becomes contaminated by foul matters from leaky sewers, cesspools, etc., especially in pervious soils. Persons should therefore always be suspicious of the quality of water derived from shallow wells, for frequently, even when bright and sparkling, it is highly contaminated.

(3.) Springs and small streams are often used to provide supplies of water, and very pure water is obtained in this way, although it is sometimes rather hard. It is either conveyed directly to the town by means of aqueducts or pipes, after the Roman plan, or collected from a gathering ground into large impounding reservoirs, and thence taken in pipes to the place to be supplied.

(4.) The water of large rivers is now frequently used as a source of supply. It is received in settling basins or reservoirs, where a deposit takes place, then filtered through beds of sand and gravel, and afterwards distributed. Most of the river water is contaminated in various ways during its passage through towns; and, without entering further into the subject here, I would merely say that it is better to obtain water that has not been contaminated, than to take water which we know has been contaminated, and then try to purify it.

(5.) Water is sometimes obtained from pervious water-bearing strata, at a considerable depth below the surface of the ground, by boring into them through the impervious strata which lie over them, and through which the water cannot penetrate. Wells with such borings from the bottom of them are known as artesian walls, from having been first generally used in the French province of Artois. The water contained in such water-bearing strata is supplied by the rain which falls on the outcrop of these strata, often at a considerable distance, and, frequently, as in London and Paris, on the hills around. This water percolates through the pervious rocks, and so gets beneath the impervious strata which lie over them after they have disappeared beneath the surface, and, being retained there under pressure, rises through borings made into the rock in which it is, through the impervious strata lying over it. This water, then, is generally, as may be expected, very pure, although it is frequently, especially if derived from the chalk, as that supplied by the Kent Company to London, very hard. Occasionally, as in some wells bored into the New Red Sandstone, it contains too much common salt to be fit for domestic purposes, which will not be wondered at when we consider that the largest deposits of salt we have, from which enormous quantities are obtained, are in the New Red Sandstone formation.

However the water is obtained, it is distributed to the houses in one of two ways, either by intermittent or by constant service. With the system of intermittent service, the water is turned on into the houses once or twice in the twenty-four hours for a short period each time. It is, therefore, necessary to have cisterns, butts, tanks, or receptacles of some kind to keep the water in during the intervals. In these, deposit occurs of the suspended matters contained in the water, and dust accumulates, especially if they are not covered, or if the covers are broken, and so the water is rendered impure. They also usually have a waste or overflow pipe, which is frequently connected with the sewers or with some part of the water-closet apparatus, and by means of which foul air finds its way into the cistern and contaminates the water. During the intervals, too, when the mains are not charged with water, foul water and foul air find their way from the soil around through leaky joints, and contaminate the water when it is next turned on, so that it frequently happens that the first water that comes into the cistern when it is turned on is quite unfit to drink. There is an enormous amount of loss with this system, which might, however, in great part be prevented. The last disadvantage of the intermittent supply lies in the fact that some delay is frequently experienced in obtaining water for extinguishing fires.

With the system of constant service, on the other hand, the pipes are always full, and so it is not necessary to have cisterns, or receptacles of any kind for the storage of drinking water, although this is frequently done. Receptacles are, however, necessary for the supply of water to closets. The pipes being always full of water under pressure, are far more likely to leak out into the soil than to be contaminated with foul matters from the soil. Still, it is not advisable on any account that water-pipes should be carried near to sewers or other sources of contamination. The water is fresher, and purer, and cooler in summer when supplied on the constant service system. The pipes are full in case of fire, and the inspection of pipes, taps, and other fittings is, as a matter of fact, carried on very much better, and less waste of water takes place under this system (although the pipes are always charged) than under the other system. It is obvious that, unless there were very strict supervision, a great waste of water would necessarily accompany the use of the constant system. For this reason, also, the water companies that have adopted that system will not allow waste pipes from cisterns to be connected with the sewers, or closet apparatus, but insist on their discharging freely in the open air; and usually in some place where any waste water running out of them would produce annoyance, so that it would be speedily noticed, and the cause of the waste remedied. It is very important, however, where this system is adopted, that there should be double reservoirs or tanks, in order that one may be used while the other is being cleared out; for if, as has been the case at some places, and notably at Croydon, the water be supplied by the intermittent system of service for a few days, defects which have produced no inconvenient results while the constant system of supply was practised (such as the connections of water-closet hoppers directly with the main water pipes), the possibility of the existence of leaky joints in the mains, through which foul matters may enter from the soil, etc., may produce the gravest results by spreading enteric fever throughout the community; and here I may mention that it is, of course, extremely improper and very dangerous to convert a cistern which is used to supply drinking water, or a water supply pipe, directly with the hopper of a water closet. The system of constant service is coming gradually into more general use, and it is very probable that water meters will be much more generally used than they are at present. A simple apparatus of this kind is Ahrbecker's water-meter, in which the water is made to pass through oblique apertures in a fixed plate into oblique or spiral passages in a cylinder which is capable of rotating, and the axle of which turns the index of a dial. The pipes, by means of which the supply of water is conveyed into the houses from the mains, are usually made of lead; this material being preferred on account of its durability, and the facility with which it can be bent in various directions. A disadvantage of it is, that certain waters attack and dissolve lead, and are thereby rendered more or less poisonous. Those, however, are chiefly pure and soft waters. Waters containing mineral salts in solution, such as those generally supplied for drinking purposes, scarcely attack lead at all; and, moreover, with waters which do attack lead, the surface of the metal becomes covered with an insoluble coating of oxide and carbonate, which protects it from further attack. Pipes made of lead lined with a thin layer of tin are sometimes used, but when the tin becomes damaged in any way, a galvanic action is set up, and the lead is dissolved quicker than ever. Varnishes of various kinds have been proposed for coating the interior of water mains and pipes. Most of them are very objectionable — one of them positively containing arsenic. Wrought iron pipes with screw joints are sometimes used for water pipes. They are certainly cheaper than lead, and it is said that they will last longer. Bends are made of almost every possible shape just as in gas pipes. In some rare instances lead pipes are attacked from the outside by water containing carbonic acid in the soil, as shown in a sample of a lead pipe which had been laid in chalk, and which was contributed to the Parkes Museum by Mr. Bostel, of Brighton.

The receptacles used for storing drinking water are made of various materials. Leaden cisterns have long been frequently used on account of their durability. They are open to the same objections as lead pipes, although from the fact that no mischief has been found to result from the use of lead pipes and cisterns at Glasgow, since it has been supplied with Loch Katrine water, which is exceedingly soft, it appears probable that the ill-effects from the use of lead in this way have been exaggerated. Galvanized iron cisterns are fast taking the place of leaden ones. They are very durable, and of course far cheaper than lead. Stone or even brickwork lined with cement are sometimes used at or below the ground level for the storage of water, and are open to no objections so far as the material is concerned. Stoneware cisterns are now made, and are admirably suited for cottages, for use in basement floors, etc. Slate cisterns are not unfrequently used for upper stories, as well as ground floors. Of course, slate in itself is an excellent material for such a purpose, but slate cisterns, unfortunately, are very apt to leak after a time, and the joints are then filled in with red lead from the inside of the cistern—a practice which is, of course, very objectionable. The use of wooden receptables, such as tubs, butts, etc., ought to be discouraged, if only because they are difficult to be kept cleansed. A self-cleansing tank is sold by the Sanitary Engineering and Ventilating Company. The bottom, instead of being flat, is made to slope from all sides towards the center, where the waste pipe is fixed. On lifting up, by means of a lever, that part of the waste pipe which stands up in the cistern, and which is fitted accurately into the commencement of the pipe at the bottom of the cistern, so as to make a water-tight joint, the water runs out of the cistern, and on account of the sloping bottom washes all the sediment away with it. The water is generally supplied to the cistern from the pipes through a tap known as the "ball valve." To it is attached, by means of a metal bar, a hollow copper sphere or ball, which floats on the water as it rises in the cistern, and when it has risen to a certain height turns off the tap. It is because these taps are liable to get out of order, that a waste or overflow pipe is necessary. This waste or overflow pipe should, in all cases, without any exception, discharge freely, as over an area, etc., so that you can see the water coming out at it. All receptacles of water should be well covered, in order that dust may be kept out of them. Nevertheless, ventilation space between the water and the cover, by means of holes provided with a grating, at the sides, is advisable.

Of course, for drinking water, we ought to choose a source of supply that is unpolluted. As Mr. Simon has said, "It ought to be an absolute condition for a public water supply that it should be uncontaminable by drainage." We ought not, then, to take confessedly impure waters and try to purify them, so as to make them fit to drink. On the other hand, it is obviously unnecessary to use very pure water, except where there is a superabundance of it, for washing the streets, flushing the sewers, and supplying the water closets, and so it may be advisable in some places to have a double supply of water, one of pure water for drinking and cooking, derived, for instance, from artesian wells, and the other of an inferior character for other uses. This has been lately proposed for London, and whatever may be said against it on the score of expense, I think most people will agree that it will be very desirable to have water to drink which has not been first polluted with sewage and then filtered. The advantage of this plan, too, was perfectly well recognized by the ancient Romans. Frontinus tells us that it pleased the Emperor (as he puts it) to order that the water supplied by certain aqueducts should be furnished to the people for drinking purposes, while that supplied by some others, from its being occasionally turbid and of inferior quality, was to be used for "viler purposes."

As, however, we do not, as a matter of fact, in the majority of instances, imitate the ancient Romans, either in this particular or in bringing pure water from a distance to supply the towns, but use the nearest water that we can get, whether good, indifferent, or bad, it is of course necessary for us to do all that we can to purify it before use. This is done on a large scale by filtration through layers of sand and gravel, after the coarser suspended matters have been allowed to deposit themselves in a settling tank. I shall not describe this method of filtration in detail here, as it is a little beside the scope of these lectures, but, as the principle on which it acts is the same as that upon which the success of most forms of domestic filter depend, I may say a few words about it once for all. The experiments made by Dr. Frankland for the Rivers Pollution Commissioners showed that when foul water was passed through layers of porous soil, or sand and gravel, the amount of organic matter in it was reduced, if two conditions were fulfilled; these are, that the filtration be downwards and intermittent. It was found that if the filtration were upwards or continuous no such purification occurred after a time. The explanation of these facts is simple. The filtering material acts in two ways. It separates mechanically suspended matters in the water that are too large to pass through the pores of the filtering material, and it also acts chemically by means of the oxygen of the air in its pores, when, as the water flows downwards through the filtering material, it percolates through by means of a number of very small streams, and so is brought into the most immediate contact with the oxygen of the air in the filtering material. Thus, the organic matter and ammonia dissolved in the water are oxidized with the production of nitrates and carbonates, and it is certain that by this means a considerable quantity of organic matter is reduced to a harmless condition. Domestic filters, clearly, ought not to be required. The water ought to be delivered sufficiently pure to drink.

And here I would remark that the average quality of a drinking water supplied to a place is not the matter of most importance, and, indeed, is rather a fallacious guide. What we want to know is the quality of the worst sample that the public are likely to be supplied with at any time. But it is not only because the water supplied varies in purity, in most instances, sometimes considerably, that domestic filters are useful, but because, as I have before remarked, especially where the intermittent system of supply is in vogue, the water, even if delivered pure, is rendered impure in the houses themselves by being stored in filthy receptacles. The majority of the filters in domestic use rely upon the principle of downward filtration. In a few the water is passed upwards through a filtering material. The chief materials used are animal charcoal—vegetable charcoal is not a good material for filtering purposes—silicated carbon, carbide of iron, spongy iron and sand. When animal charcoal is used, it must be specially prepared and well burned. If any of the animal matter be left in it, it becomes, as has been shown by the Rivers Pollution Commissioners, a breeding place for myriads of small worms which pass into the water. With the other materials mentioned, there is, of course, no risk of this, as they are made of burnt shale, or taken from the interior of blast furnaces. Some filters are placed inside the cisterns, so that all the water that is drawn off has to pass through them. These are placed on the main water pipes themselves, or in the taps. One of the former kind known as "the self-cleansing filter," in which the suspended particles in the water are prevented from getting at the filtering material by a ring of compact silicated carbon, and the water itself is made to wash the outside of the block of filtering material through which it has to pass. My experience goes to prove that filters that are always under water, cease to purify the water after a time, unless means are taken for aerating them, and in many instances I have known water to be rendered more impure by its passage through a filter which had been used in this way for a considerable time. Of forms of domestic filter, the glass decanter with a solid carbon or silicated carbon block has the great advantage that every part of it can be seen, so that it can be kept scrupulously clean. These filters will go on working perfectly well for an almost unlimited time, scarcely anything being necessary beyond cleansing the surface of the block once now and then with a hard brush. It is a very good plan to have a kind of double filtration. Sometimes the water is made to pass through a piece of sponge before falling on to the filtering material with the view of arresting the coarser suspended matters. It is far preferable, however, to use the carbon block for this purpose. In Prof. Bischoff's spongy iron filter the filtering material is always under water, and the action which goes on in it is certainly quite different to that which I have explained, and is as yet little understood. The River Pollution Commissioners have expressed the highest opinions of this substance as a filtering material. On account of the fact that the water dissolves a little of the iron on its passage through the spongy iron, it is made to pass through a layer of prepared sand afterwards, with the view of removing this, and then, in order to aerate it, it is delivered through a very small hole in a fine stream into the pure water receiver. It will thus be seen that it is rather more complicated than some of the other forms of domestic filter. The slight trace of iron that remains in the water can hardly be considered a disadvantage, at any rate in large towns.

Lastly, I must notice the filter made by the General Sanitary Engineering and Ventilating Company. In this, by an ingenious contrivance, the air passes to and from the filtered water chamber through the filtering material itself, and not by means of a small channel in the china or earthenware vessel holding the filtering material, as is the case in other filters. The water first passes through a silicated carbon block, and then falls in the form of a shower on to the surface of a layer of some loose silicated carbon supported upon a perforated plate which is not flat, but has elevations here and there on its surface. The result is, that not only when the water is drawn off by the tap does air pass through the filtering material into the filtered water chamber, but also as the water flows through into this lower chamber it forces the air out through the filtering material itself, which it is enabled to do by means of irregularities on the surface of the plate upon which the filtering material rests. If this plate were quite flat as it was heretofore made, and if there were no air pipe from the lower chamber, a balance would be established, and both water and air would cease to pass through the filtering material.

When rain water is used for drinking, and even for other domestic purposes, it is advisable to filter it, and the best form of filter for this purpose is one devised by Professor Rolleston, of Oxford. The tank to receive the rain water has two compartments, divided from one another by a vertical partition, and each having a horizontal layer of filtering material, as charcoal placed on a perforated support half way down the tank. The rain-water pipe from the roof is brought down through this filter bed nearly to the bottom of one of the compartments. The rain water then has to pass upwards through the filtering material in this compartment over the partition into the second compartment, and downwards through the filtering material there, into the lower part of that compartment, where there is a tap from which it may be drawn off. An overflow pipe is, of course, provided, so that the water cannot rise above a certain level.

In conclusion, I need only say that the number of instances in which epidemics of typhoid fever, cholera, and some other diseases, have been traced to the use of impure water, or of milk contaminated with foul water, must make it evident to everyone that it is of the greatest possible importance that we should have uncontaminated sources of water.

THE ELECTRICAL TRANSMISSION OF MOTIVE POWER.

From "Engineering."

The transmission of motive power to a distance is a subject which has, for many years, occupied the minds of mechanicians, and, until very recent times, with only very barren results. Yet this question is one of the greatest commercial importance, for a system which can, with any pretence to economy, transmit mechanical energy from one spot where there is an abundance of power with but little or no work whereby it may be utilized to another place where there is plenty of work but no power to drive it, would create a mechanical revolution in many countries, and would give to certain parts of the earth new manufacturing industries by which their internal resources might be developed to an extent hitherto altogether undreamt of.

We need not dwell here upon well-known systems for the transmission of power which are obviously specially applicable to comparatively short distances within a building or factory, such, for instance, as steam or air under pressure conveyed from a boiler or compressor by means of hollow conductors or pipes to steam or air engines, nor to the transmission of power by means either of water pressure conveyed in a similar manner, or by mechanical connections such as running belts and shafting, although quick running ropes have been used on the Continent for the conveyance of power through considerable distances from one part of a town to another, while hydraulic transmission has, as is well known, had most extensive application. All these systems have inherent drawbacks to their practical extension, beyond what, from our present point of view, we must term comparatively narrow limits. From the moment, however, when Œrsted, in the year 1819, made his brilliant discovery of the connection between magnetism and electricity, which was so splendidly developed by the researches of Arago and Ampère, and a few years later by those of Faraday, and when it became generally known that the transmission of a voltaic current through an insulated wire, wound helically around a bar of soft iron, converted that bar into a magnet, and that on the cessation or interruption of that voltaic current the iron was restored to its normal or unmagnetized condition, a vista was opened for inventors into an altogether new and fertile field for discovery. For many years the opinion held its ground that electricity was on the eve of supplanting all other natural forces, not only for motive power, but for many possible and impossible things besides, and the records of the patent offices of the various capitals of Europe and America prove that they were inundated with inventions for the conversion of electricity into motive power for driving factories and mills, drawing along carriages and railway trains, propelling ships at impossible and incredible speeds, and doing anything and everything that steam, and water, and animal power and all combined had ever done before. Notwithstanding this, the old forms of mechanical power held their own, for it had been lost sight of, with that comforting one-sidedness which is the characteristic of so many enthusiasts and inventors, that until the consumption of the materials in the battery, by which the electricity was generated, could favorably compare in economy with that of coal in the steam boiler to produce the same mechanical results, there could be no sort of commercial field for electrical motors. In the midst of all this came the discovery and subsequent development of magneto-electricity which has culminated in the modern dynamo-electric machines, to which so much attention has been called during the last two years by the progress of the electric light; but, as all such apparatus requires motive power to drive, it obviously cannot take the place of the older forms of motors, in cases where the power is near the work, for it is clearly more economical to drive machinery direct from the original source of power than through the intervention of a series of conversions and reconversions into other forms of force; and, even within distances comprised within a single building or factory, it has up to the present time been only in very special cases that electrical transmission can compare in economy with that of belts and shafting.

When, however, the distance of the work to be done is at a greater distance from the available source of energy than that through which mechanical power can be advantageously transmitted by mechanical means, then the value of electrical transmission becomes apparent, and rapidly increases with the increase of distance by which other methods of transmission are rendered more and more impossible. It is a well-known fact that all dynamo-electric generators are perfectly reversible, that is to say, if the terminals of one machine be connected to those of a second machine in action, or with a voltaic battery, it becomes an electro-magnetic engine, and is driven round under the influence of the mutual action going on between the current transmitted through its armature and the magnetic field of its electro-magnets, and the direction of rotation of the second or driven machine (assuming that the two machines are similar in construction) is the reverse of that by which the current is produced. Upon this fact as a foundation is built the whole superstructure of the transmission of power to a distance by means of electricity. From the driving of a magnetic engine by a battery to driving it by the current from a magneto or dynamo-electric machine was a step too obvious for any one to claim it as an invention, but we believe it is a fact that the first public exhibition of the transmission of mechanical power from one dynamo-electric machine to another, through a length of conducting cable, was in the year 1873 at the Vienna exhibition, forming one of the objects of interest exhibited by the Société Gramme; and the public had an opportunity of seeing a Dumont centrifugal pump lifting water, which pump was kept in rotation by a Gramme machine, which was in its turn driven by the current from a second Gramme machine, to which it was connected by wires nearly three-quarters of a mile long; and we ourselves saw in August of the following year the whole of the lathes, tools, and other machinery in M. Gramme's factory in Paris driven by connecting one of his small lighting machines by means of a belt to the shafting, from which the steam engine was disconnected, which machine acting as a magnetic engine was driven at a speed of 815 revolutions per minute by a derived circuit from one of his large machines, which was producing at the same time on a second circuit a light of 2,400 candles; thus, during this experiment, the machinery of the workshop was both driven and illuminated by electric currents generated by the same machine. At the Philapelphia exhibition and also at the Loan Collection of Scientific Apparatus in London, both of which were held in the year 1876, experimental illustrations were also given of the driving of one Gramme machine by the current produced by another.

During part of this time, however, a highly interesting and instructive series of experiments were being conducted by Messrs. Siemens Brothers, the results of which are to a considerable extent recorded in the very able paper on dynamo-electric apparatus read before the Institution of Civil Engineers in January, 1878, by Dr. Higgs and Mr. Brittle, but the vast commercial importance of the whole question of the electrical transmission of power was pointed out some ten months previous to the reading of that paper, by Dr. Siemens, in an essay which has since become historical, and which formed his presidential address to the Iron and Steel Institute, at their meeting which was held in London in the spring of the year 1877. In speaking of the possible exhaustion of the coalfields of the world at some remote period of its history Dr. Siemens called attention to other great forces of nature which might, when the time came, take the place of coal, and, in many places, supplement it even now. He reminded his hearers of the vast stores of potential energy running to waste in every part of the world in the unutilized power of its waterfalls, and drew attention to the fact that one of the falls of Niagara by itself represented a force of nearly 17,000,000 horse power, which, produced by steam engines consuming 4 lbs. of coal per horse power per hour, would involve an aggregate consumption of nearly 270,000,000 tons of coal per annum, and Dr. Siemens showed that by means of suitably arranged turbines and other hydraulic machinery, a large amount of this power might be utilized for the driving of powerful dynamo-electric machines which, by transmitting electric currents through metallic conductors to other and similar machines which would act as electro-magnetic engines, motive power might be conveyed through distances of many miles to work at a number of distant stations machinery employed in the industries of their several districts; and he estimated at that time that a copper wire or rod three inches in diameter would be capable of conveying 1,000 horse power over a distance of 30 miles; or if the currents were utilized for the production of the electric light, a moderately sized town might be illuminated at the same distance from the original source of power.

There is in connection with the transmission of power electrically by the driving of one dynamo-electric machine by the current from another, one very interesting and all-important fact which is inseparable from, because it forms part of, the principle of its action. We have seen that if a continuous current of electricity, from whatever external source, be transmitted through the coils of a dynamo-electric machine, the latter is caused to revolve in what may be called its reversed direction, and as the rotation of the armature of such a machine within the magnetic field of its electro-magnets produces an electric current, whose direction is determined by the direction of rotation of its armature with respect to the polarity of its magnets, it follows that the second machine in being driven generates a current of its own which is opposite in direction to the original current by which it is itself driven, and as the currents from both machines are generated in the same circuit it follows that the original current is reduced by an amount which is the difference of the strengths of the respective currents for the two machines. When the second machine is at rest the current from the driving machine is at its maximum, no back or opposing current being generated, but at the same time no mechanical power is transmitted, and it is found by experiment, as a little consideration of the problem would lead one to predict, that the maximum work is obtained from the second machine when its current has reduced the current from the first machine to one-half of its original strength, and thus with two equal machines connected together for the transmission of power about one-half of the work put into the first machine is reclaimable from the second.

As by Ohm's law, the strength of an electric current varies directly with the electro-motive force of its generator, and inversely with the electrical resistance of the conductor through which it is transmitted, it follows that with a constant electro-motive force (which in dynamo-electric machines is obtained when the speed of rotation is uniform) the strength of the current depends exclusively upon the resistance of the circuit which, other things being equal, is inversely proportional to the area of its cross section (which in round conductors is equal to the square of its diameter), and is directly proportional to its length. From these considerations, taken in connection with the fact that the greatest efficiency from a dynamo-electric machine is obtained when the external resistance of the circuit does not exceed the internal resistance of the machine, it follows that if a machine be transmitting power to a second machine through a certain distance, and it be desired to double that distance, a conductor would have to be employed of double the length, which would have twice the resistance; and in order to reduce the resistance of the circuit to what it was before, so as to balance that of the machine, a second conductor would have to be employed, or else a single wire of double the sectional area of the first, and this would multiply its weight, and therefore its cost four times, which would appear at first sight to be prohibitive of the extension of transmission circuits to great distances, seeing that the cost and the weight of the conductor for each circuit increases as the square of the distance transmitted; but Dr. Siemens was the first to point out a redeeming qualification, which is probably the most important, as it is at first sight the most startling, feature in connection with this most interesting subject, viz., that as at the double distance with the double conductor there is twice the area to be dealt with, a second generator can be set to work, and two machines instead of one can be driven at the double distance; and he showed from that "that it was no dearer to transmit electro-motive force to the greater than to the smaller distance, as regarded weight and cost of conductor, a result," he added, "which seemed startling, but which he nevertheless ventured to put forward with considerable confidence."

Passing from theoretical considerations to practical applications, we may remind our readers that at the conversazione given at South Kensington by the Institution of Civil Engineers and by the Society of Telegraph Engineers, a pair of Simens' machines attached to a Brotherhood three-cylinder engine, such as was figured and described in these columns a few weeks ago, were driven by the current from one of the Siemens machines in the Albert Hall through a conducting cable over half a mile in length. One of the earliest practical applications of the electrical transmission of motive power to industrial purposes was made by M. Cadiat, who in the workshops of the Sociétè du Val d'Osne, in Paris, drove a Gramme machine such as is employed for electro-plating purposes by the current from a distant electric lighting machine transmitted through two wires three millimeters in diameter, and nearly 500 feet long. In the following year MM. Chrétien et Felix established in connection with a sugar factory at Sermaize an electrical hoisting apparatus or crane, by which beet roots were unloaded from vessels lying alongside the quay, situated more than 100 metres (328 feet) from the factory from which the apparatus was driven, and by this apparatus, during one season alone, 400 tons of beet root were discharged from boats arriving at the port of Sermaize. The success which attended this installation was so great that the inventors were induced to construct electrical implements for agricultural purposes, to take the place of the steam-plowing engines generally employed. The apparatus, which is very simple, consists of two electric hauling engines, similar in the hauling apparatus to that usually employed in steam power, but differing in the motive power, which is obtained by two Gramme machines, which can be coupled to or disconnected from the winding drum by throwing into or out of action frictional gearing, by which the revolving spindles of the two Gramme machines driven from a distant engine are connected to the drums below the apparatus, which by means of a wire rope draws backwards and forwards the multiple balance plow, as in ordinary steam cultivation. In the installation at Sermaize, the motor machines were driven at a speed of 1,600 revolutions per minute, and those on the hauling apparatus at 800 revolutions; the advancing speed of the plow was from 160 feet to 265 feet per minute, and by this apparatus an area of 215 square feet was plowed in the same time.

By far the most important installation, however, of the application of the electrical transmission of motive power for agricultural operations has recently been established upon the estate of M. Menier, whose world-wide reputation rests upon a three-fold basis from the fact that he is at once a very prominent member of an extreme party of the French Chamber of Deputies, the proprietor of the most important chocolate manufactories in the world, and an eminent electrician and electrical cable manufacturer. For some weeks past a series of important agricultural experiments have been carried on by M. Menier, by which the power of water, which is abundant on his Noisiel estate, has been applied to plowing and other agricultural operations through the intervention of electricity, and we publish on page 412 of our present issue a drawing of the special form of a Gramme dynamo-electric machine employed by him in their installation both for generating the electric currents in the first instance, and reconverting them into mechanical power at the distant station.

This special form of apparatus consists, as is shown in the drawings, of a Gramme armature about 18 inches in diameter, and the same in depth, which is capable of revolving on a horizontal spindle within the magnetic field produced by eight flat electro-magnets arranged in pairs around the armature, each pair being united by a pole-piece common to both, and these four pole-pieces are fixed around the armature at equal angular distances apart, and following one another with alternating polarity, so that the poles presented to opposite ends of the same diameter of the ring are (unlike the arrangement in the ordinary Gramme machine) of the same polarity, the alternating poles being separated by an angular distance of 90° instead of 180°. By this arrangement a very powerful magnetic field is maintained, and the impelling forces in the apparatus are more uniformly distributed around the shaft to be driven. As there are four poles there are of course four neutral points in the circuit of the armature, and, therefore, there are four distributing brushes, by which the currents transmitted by the machines at the distant station, after traversing the four pairs of magnets are conducted into the circuit of the armature at the proper positions to insure their maximum effect.

With two hauling engines driven by four machines of this description M. Menier proposes to perform all the plowing and other agricultural operations on his farm at Noisiel, of 3,000 acres, and the currents by which they are worked will be transmitted by four similar machines driven by turbines which are already at the works. The power to be transmitted by the apparatus is about 36 horse power, *i. e.*, 18 horse power per winding engine, and by means of a wire rope a Fowler plow with six shares is drawn backwards and forwards, plowing six furrows at a time at a speed of nearly 200 feet per minute.

We understand that it is the intention of M. Menier to extend this electrical system of cultivation to all the farms on his estate, one of which is situated at no less distance than three miles from the driving station, the motive power at which is derived from a waterfall on the Marne, which is at the present moment actually being used for driving eight machines by which the workshops of his chocolate factory are illuminated.

We shall on a future occasion refer again to these interesting installations, and shall describe more in detail some of the more important of the apparatus employed.

NOTES ON IRONWORK.*

From "The Builder."

The branch of science which enables the engineer to determine the theoretical amount of strain in the members of any proposed structure may be said to appeal directly to ordinary intelligence, and to be on the whole simple. The science, however, depends upon data and conditions the exact influence of which can never be determined in actual practice. It is proposed, therefore, in this paper to consider briefly some of the practical questions which affect theoretical deductions, and the design, efficiency, and economy of ironwork structures generally. The precise conditions under which ironwork will be constructed and worked being indeterminable, it becomes necessary, among other matters, to have some knowledge of workshop practice, or routine, in order to determine the proper limits and importance to assign to theoretical result.

In taking out strains, it is usually

* From a paper by Mr. Graham Smith, C. E., read at the meeting of the Association of Municipal and Sanitary Engineers and Surveyors,

assumed that each member has a normal length whatever the amount of strain to which it is subjected, and that its conditions are the same as they would be were it free to turn in a plane about its extremities. Both of these assumptions are, to a certain extent, erroneous. So far from any bar having a normal length, that is, being perfectly rigid, it may be taken for granted that directly any piece of iron is subjected to a tensile or compressive strain, its length is varied accordingly. Likewise, no member of any structure is perfectly free to turn in a plane about its extremities; were it so, each junction would have to be made with an absolutely frictionless pin. In English practice, junctions are frequently made with innumerable small rivets, which render them to all intents and purposes rigid. In America, however, pin connections are employed to a very large extent, and undoubtedly, with pins and eyes properly proportioned, efficient joints may be made, and with simple arrangements of parts, theory be more closely approached than with our complicated systems with riveted joints.

Variations in the temperature of the atmosphere likewise materially affect the strains in iron structures. When constructing an iron bridge, a camber is given to it, so that when loaded it may assume a straight line, instead of exhibiting signs of apparent weakness by sagging. While testing the bridge, it is usual to measure the camber as the load is put on, and it is not uncommon to find that on a warm day the camber is greater than it was the evening before, notwithstanding that a larger amount of load has been put upon it. This anomaly is due simply to the sun warming up the top flanges, and causing them to extend, whilst the bottom flanges have not extended to a similar extent, owing to being protected from the sun by a platform or the load upon the bridge. It has been ascertained that a variation of temperature in iron of 15° Fahr. will produce the same effect as one ton actual load per square inch; therefore, a change of 82.5° Fahr. will produce the same effect as 5.5 tons per square inch actual load, which is greater than the amount of strain supposed to be put upon any bar when under its full working load. Now, although the difference between the extremes of temperature in this country may be estimated at 82.5° Fahr., the extreme temperatures only act during a short portion of each twenty-four hours; and so, owing to the mass of iron and other circumstances, the temperature of the structure is seldom the same as that of the atmosphere, consequently the iron is not affected to the full extent just mentioned. There are, of course, many positions which will at once suggest themselves where the temperature is tolerably uniform throughout the year, and where accordingly no provision need be made for expansion and contraction due to changes of temperature. In exposed positions in this country, an allowance of seven-sixteenths of an inch in each 100 feet should be made if it is wished to eliminate strains which it has been shown may be of considerable amount. Edwin Clark has placed it on record that half an hour's sunshine has more effect on the tubes of the Britannia Bridge than the heaviest rolling loads or the most violent storms.

Questions of the foregoing nature having been considered, and the strains upon the various members of the proposed structure having been determined within reasonable limits, it becomes necessary to arrange the material to meet them. It is in doing this properly and economically that the art of designing ironwork consists. In all designs every endeavor should be made to employ iron of such dimensions and weights that it may be easily procured in the open market, and require only such workmanship as can be cheaply and readily performed. By attention to these points economy will be more surely attained than by saving in the weight of iron, which may be effected by adhering more closely to theoretical refinements. As an instance of this it may be stated that the actual weight of a plate girder is always very much in excess of its theoretical weight, and it is rarely the lightest form of girder which it is possible to design to carry a load; it is yet generally the most economical type to adopt for small spans, owing to the uniformity of its parts and the simplicity of its manufacture. While mentioning plate-girders, it may be well to state that although the theoretical economical depth of all girders depends upon their description, the loads to be carried, and a variety of other circumstances, the depth of a plate-girder is often fixed by one consideration alone, and that of a practical nature quite beyond the control of the designer. It is simply the fact that plates cannot be rolled at ordinary rates over 4 feet six inches in width, so that the maximum depth of ordinary plate-girders is fixed at 4 feet 6 inches. If this depth is exceeded, it becomes necessary to plate the web vertically, which will enhance the cost of the work to an extent exceeding the saving likely to result from conforming more nearly to any greater depth which theory might dictate. In arranging the flanges, although theoretically the section of metal should be reduced at certain points, it is generally desirable, when a limited number of girders are to be made from one design, to keep the plates as nearly uniform in thickness as possible, rather than to vary their thickness so as to approach more closely to the amount of metal required to meet the strain. However, where a large number of girders are to be constructed from the same design, the plates may be varied in thickness without increasing in any way the cost of the work, as the plates can be ordered in batches from the rolling-mills and relegated to their respective girders in the manufacturer's yards.

At one time much of the iron employed for girder and bridge building came from Staffordshire; consequently specifications were prepared in such a manner that iron from this district might comply with their stipulations. These specifications have been copied and re-copied even up to the present time, notwithstanding that Staffordshire iron is now rarely put into ordinary work, for the reason that the sizes of the iron supplied from this district are small when compared with those from the north country. This is owing to the Staffordshire mills working with plant which was put down many years since, whilst the ironworks in the Cleveland district are provided with more modern machinery and improved appliances. A South Staffordshire plate to cost the ordinary market rate must not be over 4 cwt. in weight, 15 feet in length, and 4 feet in breadth, and about 30 superficial feet in area; whereas Cleveland plates can be procured without additional cost up to 21 feet in length, 4 feet 6 inches in width, and 12 cwt. in weight, providing the area does not exceed 56 superficial feet. Although plates from the latter district may be obtained possessing as great a tensile strength both with and across the fibre as those from Staffordshire, they are not as a rule equal to the latter in toughness. Extra care should therefore be taken to test and thoroughly ascertain the quality of the iron, as it is sometimes very brittle. No attention whatever should be paid to "brand," as it is no criterion by which to judge of the qualities of iron usually employed for the construction of ordinary ironwork. A very fair specification for girder iron is 20 tons per square inch and six per cent. elongation with the fibre; 18 tons per square inch and three per cent. elongation across the fiber for plates; 22 tons per square inch and nine per cent. elongation for L and T's; and 24 tons per square inch and 15 per cent. elongation for rods and bars. These elongations ought to be taken on a testing section of uniform width for a length of $6\frac{1}{4}$ inches. In a length of $6\frac{1}{4}$ inches there are one hundred sixteenths of an inch, so that each $\frac{1}{16}$ elongation after testing represents one per cent. In preparing all samples for testing they should be drilled out of the plate angle or bar, and be either chipped or slotted to the required dimensions, and all tool marks carefully filed out, and the parallel portions should run in with curves of large radii to the portions through which the pin-holes are drilled. In the event of there being the slightest shoulder at either of these points, it will have the same effect as a nick in the iron, which will generally render worthless the test for both tensile strength and elongation. With a little experience the quality of a plate may be determined to some extent by breaking the corner off over an anvil, and by inspecting the punchings from the plates. If the iron is brittle and untrustworthy, the punchings will show cracks in all directions if the punch be working as ordinarily with a little clearance, whereas if the iron is good and reliable slight cracks only will be perceptible—all running in the direction of the fiber. Whilst these workshop tests can be carried out in the manufacturer's yard by the inspector during the progress of the work, all tests requiring to be made with hydraulic presses or steelyards, should be conducted by independent authorities, such as Mr. Kirkaldy. After the material has been tested and passed, and the structure put together, it becomes necessary to apply a proof-load, which consists of gradually placing on the structure a weight somewhat exceeding its working load. This is requisite in order to ascertain if the workmanship is up to the proper standard. It must, however, be always remembered that a proof-load is no test of the strength of the structure or the quality of the material. If the iron is hard and brittle it will give less than a material of more desirable quality, and the structure will apparently be stronger, but it is needless to state that such is not the case. Again, any part may be on the point of breaking, and yet not yield sufficiently to materially alter the deflection. Likewise, although a structure may stand the application of a proof-load at the time of testing, it does not follow that it will stand repeated applications of loads of even less amount than the proof-load. Fairbairn's experiments, carried out many years back, demonstrated this fact. He found that when the strain on the iron of a beam was between six and seven tons per square inch, the beam sustained an unlimited number of applications of the load producing this strain; but when the load was increased so as to put a strain of from eight to nine tons per square inch on the iron, the beam failed with comparatively few applications of the load.

ON THE STRENGTH AND ELASTICITY OF MATERIALS.

By WM. JAMES MILLAR, Secretary to the Institution of Engineers and Shipbuilders in Scotland.

From the Proceedings of the Institution of Civil Engineers.

The object of the author is briefly to describe some experiments upon the strength and elasticity of materials. During the course of his practice he has made numerous tests of cast iron bars, the results of which are given in

TABLE I.

Dimensions of Bars.			Number of Tests.	Average Ultimate Strength.	Average Ultimate Deflection.	Average Modulus of Rupture.	Remarks.
Span.	Breadth.	Depth.					
Inches.	Inches.	Inches.	Bars.	Lbs.	Inch.	Lbs. per Square inch.	
36	1	2	1,344	3,740	.400	50,490	The bars were loaded at the center.
36	1	1	50	801	.583	43,254	
36	2	1	1	1,763	.843	47,601	
..	..	..	Links. 66	21,122	..	..	

From the above results the following constants and rules have been determined:

$$W=\frac{25\times b\,d^2}{S};\ D=\frac{W\times S^3}{b\,d^3}.0036;$$

$$T=\frac{.44\times W\times S}{bd^2};\ W=\frac{T\times bd^2}{.44\times S},$$

when W=ultimate load in cwt. at the center of the bar; S=span in feet; b= breadth in inches; d=depth in inches; D=deflection in inches; and T=tenacity in tons per square inch.

It was found that when the bar broke at, or close to, the center, the fracture was straight; but when fracture occurred at points removed from the center, the form was curved: hence the form of fracture invariably shows the position of fracture. The author has also proved by experiment that this law applies to bars of steel, glass and sealing wax. These curved fractures all pointed towards the point of application of the load, the curve increasing with the distance of fracture from the center of the bar. In no case was a wood-shaped piece forced out of the compressed side of the bar; the fractured parts always fitted together. Flakey or lumpy fractures with a purplish gray color indicated strength. Dull smooth surfaces, crumbling to the touch, indicated weakness; a sparkling metallic look indicated soft iron. The breaking of the outer surface, or skin, did not materially affect the strength.

When bars had been subjected to a high load, it was found in many cases that, on a second application, they broke below the first applied load. Vibration, obtained by tapping the bar when loaded, had also the effect of causing rupture.

Some exceptionally strong bars showed a decrease of deflection with increase of load, as will be seen by

TABLE II.

Average of fourteen bars unbroken.........Loads, lbs.	3,360	3,920	4,480
Deflection*.............................Inch	.327	.317	.313
Single experiment.........................Loads, lbs.	3,360	3,920	4,480
Deflection..............................Inch	.380	.370	.350
Set..................................."	.008	.002	.000

Experiments to determine the law of set showed that, at high loads, the set decreased for additional loads. There was also a decrease of set for repeated applications of the same load; but when starting with small loads, and gradually rising until fracture took place, the set appeared to increase, then remain steady, and afterwards decrease. Some of these results are shown in

TABLE III.

Average of ten bars unbroken ....Loads, lbs.	3,360	3,920	4,480
Deflection.............................. Inch	.341	.367	.388
Set...................................... "	.026	.014	.008

TABLE IV.

Load applied, 2,800 lbs.	Bar No. 1.		Bar No. 2.		Bar No. 3.		Bar No. 4.	
	Deflection.	Set.	Deflection.	Set.	Deflection.	Set.	Deflection.	Set.
	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.	Inch.
1st application of load.	.302	.021	.336	.020	.290	.012	.298	.015
2d " "	.282	.003	.317	.005	.290	.005	.296	.002
3d " "	.279	.001	.310	.001	.286	.003	.285	.002
4th " "	.278	.000	.312	.000	.282	.000	.281	.000
5th " "	.276	.002	.313	.000	..	..	..	..
6th " "	.273	.001	.315	.000	..	..	..	..
	Finally broke about 3,500 lbs. Deflection, .403.		Finally broke at 4,270 lbs. Deflection, .518.		Finally broke at 4,330 lbs. Deflection, .455.		Finally broke at 3,760 lbs. Deflection, .395.	

Often when near the breaking point a slight increase of deflection was observed to take place suddenly. From various observations this change appeared to occur at loads of about 97 per cent. of the ultimate strength.

In experiments to determine the relative strengths of hot-run and dull-run metal, the bars were cast from the same metal, the first being cast as hot as possible, and the others from metal which had been allowed to cool until it would only

*All deflections mentioned in the tables are those for corresponding loads. The deflection for each experiment being noted, a re-adjustment of the deflection circle to zero was made, and the experiment repeated.

just flow into the mould, with the result shown by Table V.

It will be observed that the dull-run metal gives the highest breaking strength, but the deflection is less than with the hot-run metal.

From experiments upon the cooling of bars, it was found that bars cooled in the mould gave higher results than those cooled in the air; thus:

The average of nine bars cooled in the mould was 4,206 lbs. with a deflection of 0.404 inch.

The average of ten bars cooled in the air was 4,009 lbs., with a deflection of 0.396 inch.

So far as the author has been able to determine, the action of severe frost on bars does not affect their strength.

Table V.

——	Hot Metal.		Dull Metal.	
	Ultimate Strength.	Ultimate Deflection.	Ultimate Strength.	Ultimate Deflection.
	lbs.	Inch.	lbs.	Inch.
Average of ten bars............	3,524	.402	3,619	.371

The results of experiments, made at the instance of Mr. David Rowan, M. Inst. C.E., and recorded by the author, on bars of forged and rolled iron, subjected to bending stress in a similar manner to the cast iron bars, but with the application of the same load, are given in Table VI.

These experiments were repeated, with increasing loads, when the results arrived at are shown in Table VII.

Table VI.

Load applied, 37 cwt. Forged Bar.	Deflection.	Set.	Load applied, 37 cwt. Rolled Bar.	Deflection.	Set.
Span 36 inches; breadth $\frac{17}{16}$ inch; depth 2 inches.	Inch.	Inch.	Span 36 inches; breadth 1 inch; depth 2 inches.	Inch.	Inch.
1st application of load..	.230	.031	1st application of load.	.700 rising to .870	.535
2nd " " ..	.200	..			
3rd " " ..	.180	.062			

Table VII.

Forged bar.............cwt.	32	34	35	37	Left in machine at 37 cwt. for seventeen hours. Deflection .180, and set .093 inch.
Loads.................lbs.	3,584	3,808	3,920	4,144	
Deflection...........inch.	.180	.175	.180	.192	
Set.................. "	None.	..	..	None.	
Rolled bar.............cwt.	26	26	28	30	32
Loads.................lbs.	2,912	2,912	3,136	3,360	3,584
Deflection...........inch.	.150	.150	.160	.170	.190, rising to .235 inch.
Set.................. "	None.	None.	None.	..	Set .062 inch.

The critical points in these bars appear to lie about 36 and 30 cwt. Taking these loads as the limit of elasticity, the modulus of longitudinal strength or tenacity would be, $f=\frac{6\times W\times S}{4\times bd^2}$, where W=load in lbs., S=span in inches, b and d being the breadth and depth in inches. Substituting the values as given for the above bars, then—

in the forged bar,

$$f=\frac{6\times 3{,}920\times 36}{4\times \frac{17}{16}\times 2^2}=49{,}807 \text{ lbs.},$$

and

in the roll bar,

$$f=\frac{6\times 3{,}360\times 36}{4\times 1\times 2^2}=45{,}360 \text{ lbs.}$$

Taking the formula, $E=\frac{W\times S^3}{4Dbd^3}$, as the modulus of elasticity, then, when W=3,920 lbs.,

for the forged bar,

$$E=\frac{3{,}920\times 36^3}{4\times .180\times \frac{17}{16}\times 8}=29{,}880{,}000 \text{ lbs.},$$

and

for the rolled bar,

$$E=\frac{3{,}360\times 36^3}{4\times .170\times 1\times 8}=28{,}800{,}000 \text{ lbs.}$$

In the above formula D is the deflection in inches.

If the cast-iron bars be taken at loads where set disappears, and the whole deflection becomes elastic, the modulus of elasticity will vary from 14,500,000 to 18,600,000 lbs.

The author inclines to the belief that the so-called "set," observed in cast iron bars, is really due to the relief of the particles from strain produced in cooling, and is not similar to the permanent set observed in wrought iron and steel. From the results of the experiments on the cast-iron bars the elastic deflection appears to vary proportionally with the load.

THE CHORDEL: AND ITS APPLICATION TO THE GENERAL SECTION OF AN ANGLE.

By J. BRUEN MILLER.

Written for VAN NOSTRAND'S MAGAZINE.

A Chordel is the path of a point in a plane, moving in such a manner that if, with a fixed point in the plane as a center, circumferences of circles be described, the arcs of these circumferences included between the path of the generating point and a fixed line in the plane, will each of them subtend a given portion of a right line, as a chord, the same number of times.

The given portion of a right line is called the ELEMENT; the fixed point in the plane, the FOCUS; and the fixed line the DIRECTRIX.

Chordels are classified:

1st.—According to the number of times the element is subtended as a chord; whether once, twice, n times, &c.

2d.—According to the nature of the directrix; whether a straight or curved line, an hyperbola, ellipse, etc.

3d.—According to the position of the focus, whether on the directrix, or at a certain distance from it.

A chordel in which the element is subtended n times, as a chord, whose directrix is a right line, and whose focus is on the directrix, is called—

A chordel of n *elements, and rectilinear and focal directrix.*

PROBLEM I.

TO CONSTRUCT A CHORDEL OF n ELEMENTS AND RECTILINEAR AND FOCAL DIRECTRIX.

Let n equal any number, as 2, and let AB, (Fig. 1, p. 207) be any given right line, CD, any definite portion of a right line, and F, any point on AB. With AB as the directrix, CD, the element, and F, the focus, it is required to construct a chordel of two elements. With F as a center, describe the arcs GEH, G′E′H′, G″E″H″, etc., and at the points E, E′, E″, etc., where these arcs cut AB, lay off on these arcs in both directions, the chords Eh, hH; Eg, gG; E′h', h'H′; E′g', g'G′; E″h'', h''H″; E″g'', g''G″, etc., each equal to the element, CD, and to each other. The points H, G, H′, G′, H″, G″, etc., are points in the required chordel, since the arcs described from F as a center, and intercepted between these points and AB each subtend CD as a chord, twice; in the same manner, an indefinite number of points may be found and the chordel XPCY constructed. The same process may be employed when n equals any other number.

Corollary 1.—It will be seen from the figure that the chordel is a curve, extending indefinitely in the directions PX and PY; that it is *symmetrical* in reference to the directrix, if the focus be upon it, and also, if the same process be carried on to the right of F, a precisely similar figure will be the result, and the curve will have two branches.

Corollary 2.—The points h, g, h', g', h'', g'', etc., are points in a chordel of *one element*, whose element is CD, directrix AB, and focus F. Hence the process given above may be used in the construction of any species of chordel.

Corollary 3.—The point C, or the *limit* of the curve, may be found by an analysis; for it must be at the intersection of the directrix with the circumference of a circle whose center is the focus F, and which must contain CD as a chord twice; or the circumference of the circle CMDN, whose diameter is CD. FC, the radius of CMDN is therefore

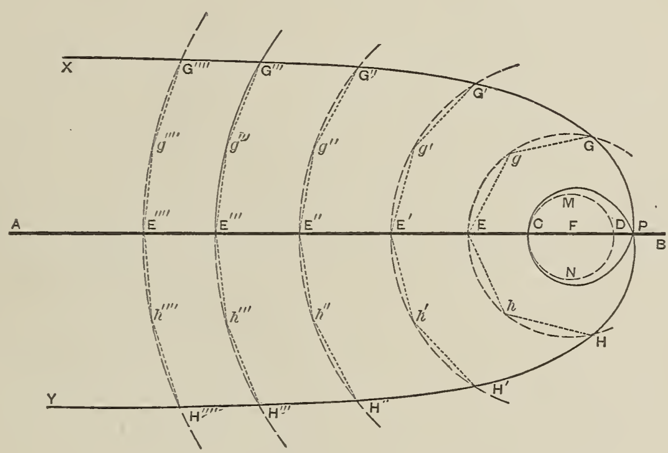


Fig. I.

one-half of CD, and the limit of the chordel XPCY is therefore a point C, on the directrix AB, at a distance from the focus equal to one-half the element. By a similar mode of reasoning, the point P, where the curve again cuts the directrix, may be found, and in general, all points of chordels common to the directrix and the curve itself.

It follows from what has been demonstrated that:

The chordel is a plane curve, generated by one of the points of intersection of a series of right lines which shall intersect in such a manner that each line will contain two points of intersection at a given distance apart, the lines moving so that they shall constantly be in the same plane, their points of intersection equally distant from a fixed point in the plane, and one of their points of intersection constantly remaining on a fixed line in the plane.

It is evident from this definition, that any chordel may be constructed *mechanically*, as follows:

Take n rods of equal length, and hinge their extremities; to these extremities attach cords of equal length, and fasten them together at the ends. Now upon any plane surface lay another rod whose edge shall be of the nature of the directrix of the required chordel; upon a certain point in this plane insert a pin or tack around which the cords may pass; lay the hinged rods on the plane, pass the cords around the pin, and move them together in the plane, so that the cords are constantly taut and the end of the first rod pressed against the fixed rod in the plane. Any one of these hinged extremities will describe a chordel, of which the length of the hinged rods is the element, the rod in the plane the directrix, and the pin or tack the focus. If the fixed rod has a straight edge, the pin inserted against this edge, and a pencil point attached to the extremity of the nth hinged rod, this pencil point will describe a chordel of n elements and rectilinear and focal directrix.

DEFINITIONS.

Any portion of a chordel, cut by the directrix is *segment* of that chordel. Thus, PX, PY, etc. (Fig. 1), are segments of the chordel XPCY. PX is *reverse* to PY.

PROBLEM II.

TO DIVIDE AN ANGLE INTO n EQUAL PARTS.

Let ACB (Fig. 2) be any plane angle and let n equal any number, as 3. It is

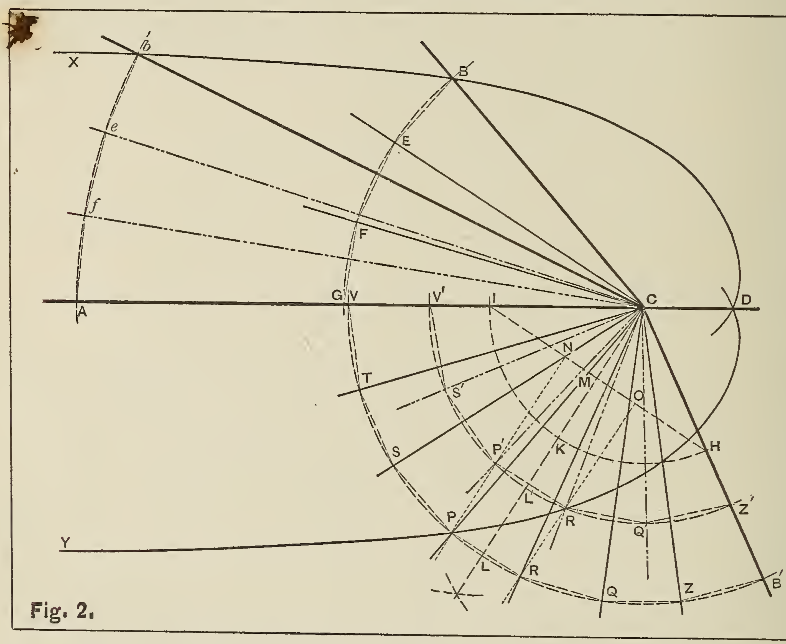


Fig. 2.

required to *trisect* the angle ACB. Prolong one of the sides of the angle, as AC, indefinitely, and lay off any convenient portion, as CD. Now with AC produced as a directrix, CD as the element, and C the vertex of the given angle, ACB, as the focus, construct a chordel of 3 elements. DX will be a segment of this chordel. Through the point B, where BC cuts DX, describe the arc BG from C as a center; then will BG measure the angle ACB. But from the nature of the curve of which DX is a segment, the arc BG subtends CD as a chord, three times. Therefore, laying off the chords GF, FE and EB, each equal to CD and to each other, the arcs GF, FE and EB will be equal to each other, and each to one-third the arc GB. Hence the angles GCF, FCE and ECB are each equal to one-third the angle ACB, and to each other, and the angle ACB is *trisected* as required. Had n been taken as equal to any other number, the same process could be employed.

Corollary 1.—*By means of the segment* DX, *any other angle may be trisected.* Thus the angles ACf, fCe and eCb are each equal to one-third the angle ACb and to each other. The same is obviously true of the *reverse segment* DY.

Corollary 2.—If $\frac{n-1}{2}$ be an *integral number*, or if n be an *odd number*, a shorter process may be employed. Thus, let n equal the odd number, 7, and let it be required to divide the angle ACB′ (Fig. 2) into seven equal parts. $\frac{n-1}{2}$ will equal 3. With AC produced as a directrix, C as a focus, and CD the element, construct a chordel of 3 elements. DY will be a segment of this chordel. With C as a center, and with any convenient radius, describe the arc HKI, measuring the angle ACB′. Draw the chord, HI of this arc, and bisect the angle ACB′ by the straight line CL. CL will, therefore, bisect the arc HKI, and its chord HI. From the point M, where CL bisects HI, lay off on HI, MN, and MO, equal to each other and each to one-half the element CD, and at the points N and O, erect NP, and OR, perpendicular to HI, and therefore parallel to each other. Through the point P, where NP cuts the segment DY, describe the arc B′LV with C as the center, and produce OR until it cuts B′LV at R. Since NP and OR are perpendicular to HI, they are parallel to the radius CL which bisects the chord HI, and since MN and MO are equal, the parallels NP and MO are equally distant from CL, whence the arcs RL and PL are equal. But since CL bisects the arc PR, or the sum of the equal arcs RL, and PL, the chord RP, subtending that arc is also bisected by CL, whence CL is perpendicular to RP, and therefore NP and OR are also perpendicular to RP. But since OR and NP are parallel, RP is equal to NO, and since OM and NM are equal to each other, and each to one-half the element CD, the sum of OM and NM or its equal, RP is equal to the element CD. The arc VP is equal to the arc B′R; for since CL bisects the whole arc, B′LV, and RL equals PL, the difference of B′L and RL, or the arc B′R, is equal to the difference of VL and PL, or VP. The arc VP subtends CD as a chord three times from the nature of the curve DY; therefore the arc B′R must also subtend CD as a chord three times; but PR, or the chord of the arc RLP, is equal to CD, whence the whole arc B′LV, measuring the angle ACB′, or the sum of the arcs B′R, RP, and PV must subtend CD as a chord seven times, and if from the extremities of these chords straight lines be drawn to C, the angles thus formed, B′CZ, ZCQ, QCR, RCP, PCS, SCT, and TCV, will be equal to each other, and each to one-seventh the whole angle ACB′. In like manner could any other angle be divided into seven equal parts by means of the segment DY or its reverse segment DX, and the same process of reasoning may also be employed when n equals any odd number.

Corollary 3. If through the point R′ where OR cuts the segment DY of a chordel of 3 elements, an arc be described measuring the angle ACB′, and CD be applied as a chord, the angle ACB′ may be divided into *five equal parts*. For, (Corollary 2), the arcs Z′R′, and V′P′ are equal to each other, and the chord R′P′ of the arc R′L′P′ is equal to CD, whence V′P′ subtends CD as a chord twice, as does Z′R′, and the whole arc Z′L′V′ subtends CD as a chord five times, whence the angles Z′CQ′, Q′CR′, R′CP′, P′CS′, and S′CV′, are equal to each other and each to one-fifth the whole angle ACB′. In like manner the fifth part of any angle could be found; and in general, if the chordel be one of $\frac{n-1}{1}$ elements, the $\frac{1}{n-2}$ *equal part*.

NOTE.

The discussion of the chordel has not been carried further than it may directly apply to the nth section of a plane angle, nor is the process employed above the only one by which a chordel may be used in accomplishing this result. Sufficient has been demonstrated, however, to show the simplest process, and also to show that by a chordel of $\frac{n-1}{2}$ elements and focal and rectilinear directrix, any plane angle may be divided into n, $n-2$, and $\frac{n-1}{2}$ equal parts without the use of any combinations to obtain these results. Of course, by combining, we may obtain the $\frac{1}{n^2}$, $\frac{1}{n^3}$, $\frac{1}{n(n-2)}$, etc. equal part, and the number of divisions may thus be increased. It may be claimed for the chordel, however, that it affords the only mathematical solution yet known to the GENERAL SECTION OF THE ANGLE.

ON THE ACTION OF JETS OF WATER ON CURVED VANES.

By Prof. I. P. CHURCH, Cornell University.*

Contributed to Van Nostrand's Engineering Magazine.

1. In considering the effect of jets of water on vanes, Weisbach and Rankine make use of different methods; the latter first finds an expression for the impulsive force of the jet against the vane, and thence the work done per second, if the vane is moving with a uniform velocity; while the former, by comparing the final, with the initial absolute kinetic energy of the mass of water passing over the vane per second, derives an expression for the energy transmitted to the vane per second, and from that passes to the impulsive force. Weisbach's method requires the vane to be in motion, while both methods employ, at the very outset, the quantity of water delivered over the vane per second. It has occurred to the writer, therefore, that, since the pressure against the vane has a finite value at any instant of time, it would be analytically much more direct and intelligible, to determine the total force in any assigned direction, by summing up the components, in that direction, of the pressures exerted against the vane by all elements of that portion of the stream which is *at that instant* in contact with the vane. The following discussions, relating to vanes and to one form of turbine, have been developed in accordance with this view:

The investigation of the circumstances of motion of a particle moving without friction in a groove on a rotating disk, (especially its pressure against the side of the groove) as preliminary to the problem of the turbine, will, it is hoped, be found interesting on its own account.

2. As a fundamental equation we must use the proportion $\frac{P}{G}=\frac{p}{g}$; *i. e.*, the force P, which, at any instant, is changing, at the rate p, that component of a body's velocity which lies in the direction of the force, bears to the attraction of gravity on that body, G, the same ratio as that rate of change (or acceleration), p, does to the rate of change of the velocity of a free fall.

Hence $P=\frac{G}{g}p=Mp$, M denoting the mass or amount of matter in the body.

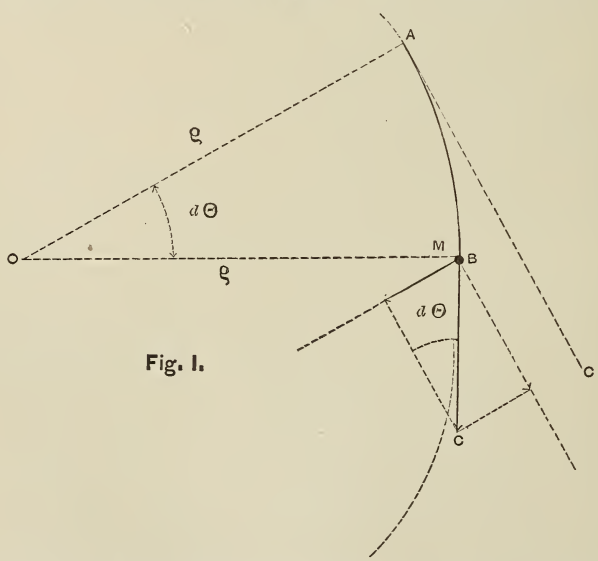


Fig. I.

3. Hence, Fig. 1, if a particle whose mass is M, moving with a velocity c, is deviated from the straight tangential path AC, into the curved path AB, by the smooth curved guide whose radius of curvature at A is ρ, the pressure of

* Written March, 1879.

the guide against M (or the re-acting pressure of M against the guide) is $P = M \frac{c \sin d\theta}{dt}$, since $c \sin d\theta$ is the change of velocity in the direction A*o* in the time dt; *i. e.*, $P = Mc \frac{d\theta}{dt}$, putting $\sin d\theta = d\theta$ since we are only concerned with the pressure at a single point of the curve. But $AM = \rho d\theta = c dt$, or $\frac{d\theta}{dt} = \frac{c}{\rho}$; $\therefore P = \frac{Mc^2}{\rho}$ the ordinary form for a deviating or centripetal force. If the guide is itself moving, each of its points with the *same* parallel velocity, the form of P remains the same, but c then denotes the velocity of M *relatively* to the guide.

4. Apply this to the case of a stream of water impinging *tangentially* upon a smooth curved vane, which is constrained to move in the direction of the stream, but at a less velocity v.

Parallel borders not shown in the figure (Fig. 2) may be supposed to keep the stream at right angles to the elements of the cylindrical surface.

Let F = cross-section of the stream, which can be considered constant over the whole arc OB = s. From the preceding we know that an elementary mass

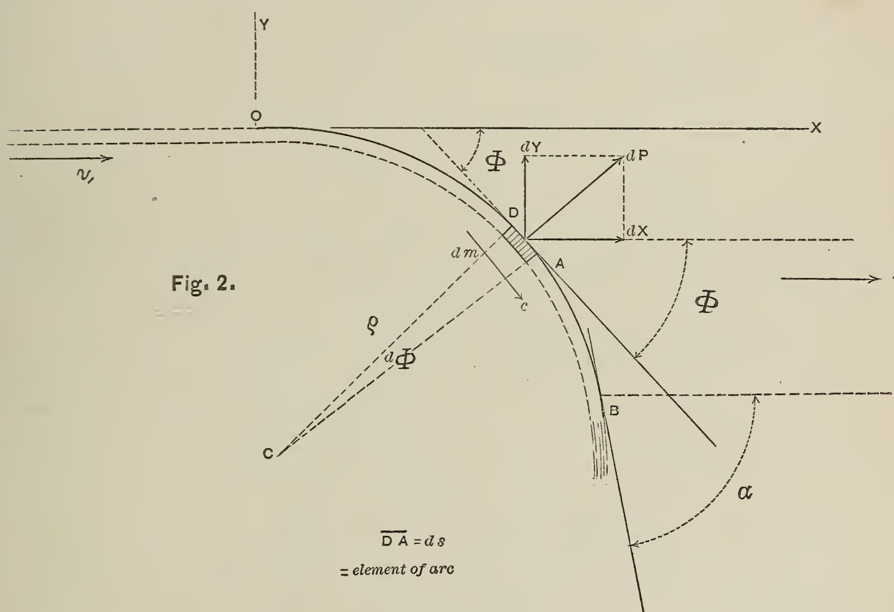


Fig. 2.

of the stream, $dm = \frac{F ds \gamma}{g}$, (where γ = weight of cubic unit of the liquid) presses normally with a force $dP = \frac{dmc^2}{\rho}$ against the vane, (c denoting the relative velocity $v_1 - v$ of the water) whose component in the direction of the vane's motion is

$$dX = dP \sin \Phi = \frac{dmc^2}{\rho} \sin \Phi = \frac{F\gamma c^2}{g} \frac{ds \sin \Phi}{\rho}.$$

But $ds = \rho d\Phi$ and substituting and making the summation for the whole arc of contact, we have the total impulse in the direction of the vane's motion, at the instant considered,

$$P_x = \int dX = \frac{F\gamma c^2}{g} \int_0^a \sin \Phi d\Phi = \frac{F\gamma c^2}{g} [1 - \cos a]$$

which, since $Fc = Q$ = quantity of water passing over the vane per second, may be written

$$P_x = \frac{Q\gamma}{g} c [1 - \cos a]$$

(compare Coxe's Weisbach p. 1007). Since this result does not depend on the length of curve, or its curvature, but only upon the relative velocity c, and the total angle of deviation α, we may reasonably conclude that the very short turn (Fig. 3) occasioned when the vane is straight, but c and α the same as before, produces a force $P=\frac{Q\gamma}{g}c[1-\cos\alpha]$nearly, and the work done per second

$$=\frac{Q\gamma}{g}c[1-\cos\alpha]v.$$

Some of the water, of course, takes the direction AD, being deviated an angle $(180°-\alpha)$ from its original direction, and the nearer α is to 90° the more water follows AD. Weisbach considers this case on p. 1012 (Coxe's translation), whereas Rankine seems to neglect the circumstance altogether, except when $\alpha=90°$, which, of course, gives the same P_x as if all the water had been deviated to one side only.

5. Supposing (Fig. 4) a curved vane to

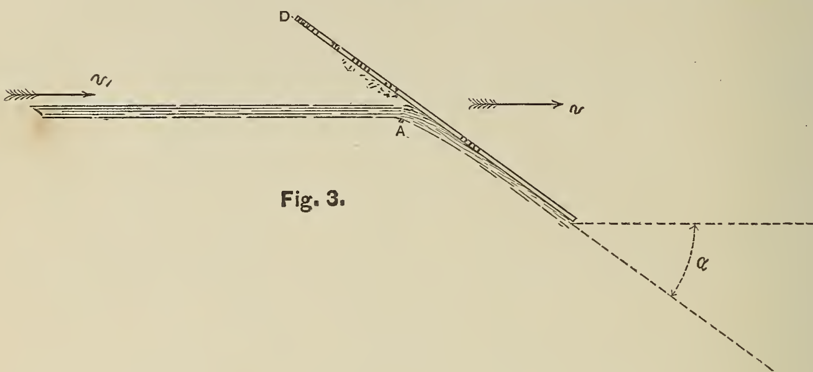


Fig. 3.

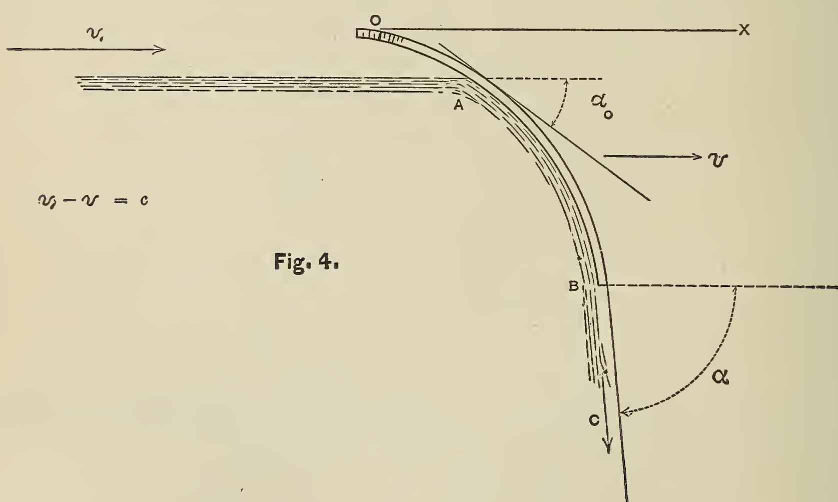


Fig. 4.

receive the water obliquely, instead of tangentially, other circumstances being the same as in Fig. 2, we have the impulse in the direction of X equal to the sum of two parts; that due to the sudden turn at A, $=\frac{Q\gamma}{g}c[1-\cos\alpha_0]$; and that due to the presure of the elements along AB against that arc, which $=\frac{Q\gamma}{g}c\int_{\alpha_0}^{\alpha}\sin\Phi d\Phi=\frac{Q\gamma}{g}c[\cos\alpha_0-\cos\alpha]$

Whence the total X impulse is $P_x=\frac{Q\gamma}{g}c[1-\cos\alpha]$ = same as if the water had impinged tangentially at O, (neglecting the alteration in the action of what water takes the direction AO.) By making $\alpha=180°$ and $v=\frac{v_1}{2}$ we cause the absolute velocity of the particles of water to be$=o$, on leaving the vane. That is, since, in that case, $c=v=\frac{v_1}{2}$, work

$$\text{done per second}=\frac{Q\gamma}{g}\frac{v_1}{2}[1-(-1)]\frac{v_1}{2}=\frac{Q\gamma}{g}\cdot\frac{v_1^2}{2}$$

=total initial kinetic energy of the quantity passing over the *vane* per second, and not of that $[Q_1]$ delivered per second from the stationary nozzle from which we may suppose the jet to be issuing. [Failure to recognize this distinction between Q and Q_1 makes Weisbach's work on p. 1010 (Coxe) incorrect. With his notation, if v is to vary, $Q=F\ (c-v)$ is also variable, and not constant, as he has treated it; hence the correct result in that problem is, Pv becomes a maximum for $v=\frac{c}{3}$, and not $v=\frac{c}{2}$. That Weisbach here incorrectly regards Q as the delivery from the nozzle, is shown in the example at the foot of the page referred to. This discussion Prof. Du Bois has reproduced without comment in the introduction to his translation of a portion of Weisbach's Vol. II. Similarly Prof. Trowbridge (p. 250 of the Eng. Mag. for March, '79) regards M as constant while u varies, whereas it is a function of u.

If a *series* of vanes is provided, connected with the same machine for doing work, and receiving the impulse of a single jet in turn, when the succession is once established it *is* true that the work

$$\text{done per second}=\frac{Q_1\gamma}{g}c\,[1-\cos\alpha]\,v \text{ and}$$

$$\text{not}=\frac{Q\gamma}{g}c\,[1-\cos\alpha]\,v;$$ for the portion of the jet intercepted between two successive vanes is at liberty to finish its work on the forward vane, while additional work is being done on the hinder one; while the rate of work done on each vane is$=\frac{Q\gamma}{g}c\,[1-\cos\alpha]\,v$ so long as that vane receives any water].

6. In Figs. 2, 3, and 4, the direction of

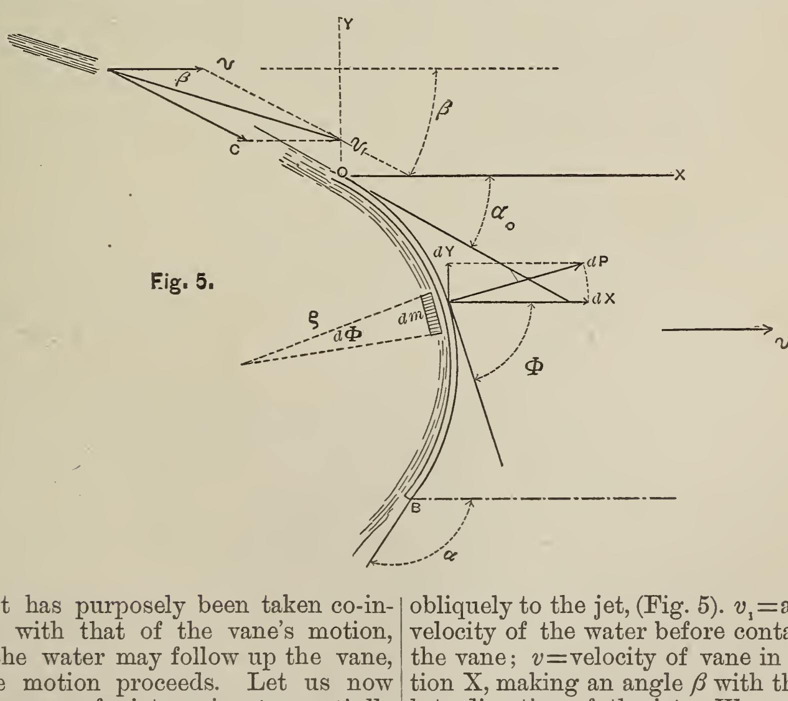


Fig. 5.

the jet has purposely been taken co-incident with that of the vane's motion, that the water may follow up the vane, as the motion proceeds. Let us now take the case of a jet coming *tangentially* into contact with a curved vane moving obliquely to the jet, (Fig. 5). v_1=absolute velocity of the water before contact with the vane; v=velocity of vane in a direction X, making an angle β with the absolute direction of the jet. We easily find $c=\sqrt{v_1^2+v^2-2v_1v\cos\beta}$, the relative velocity of the water, and $\alpha_0\left(\text{from } \sin\alpha_0=\frac{v_1\sin\beta}{c}\right)$ the angle between c and X. As in connection with Fig. 2, so here we have by successive substitution,

$$P_x=\int_O^B dX=\int d\,P\sin\Phi=$$

$$\int\frac{dmc^2}{\rho}\sin\Phi=\frac{Q\gamma}{g}c\int_{\alpha_0}^{\alpha}\sin\Phi\,d\Phi$$

$$=\frac{Q\gamma}{g}c\,[\cos\alpha_0-\cos\alpha]$$

=the force in the direction of the vane's motion, acting at the instant.

Here $Q=Fc$=volume of water passing a point on the vane per second (or Q= rate of passage over the vane) and its use arises incidentally, as a matter of mere algebraic convenience. As P_x is independent of the extent of arc, we may regard its value, found above; as still applicable to a sharp turn (Fig. 6), if $\alpha-\alpha_0$ is not large, *i. e.*, if we neglect the change in the action of the small amount of water taking the direction AO. Hence for Fig. 6 we have $P_x=\frac{Q\gamma}{g}c[\cos\alpha_0-\cos\alpha_1]$.

The straight portion AD, of course exerts no pressure against the flat vane By uniting these two cases in the general case Fig. 7, P_x is the sum of the two parts $\frac{Q\gamma}{g}c\,[\cos\alpha_0-\cos\alpha_1]$ due to the sud-

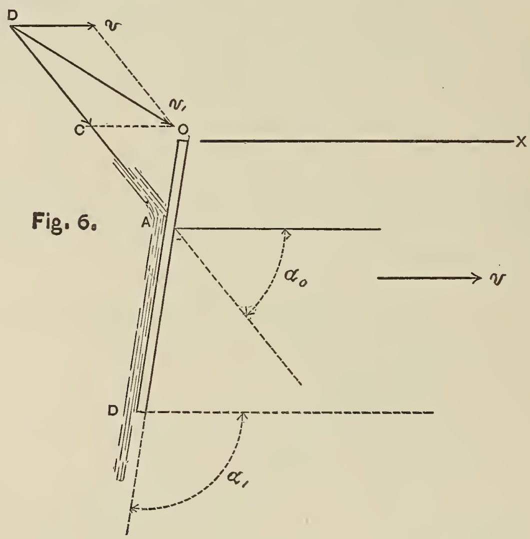


Fig. 6.

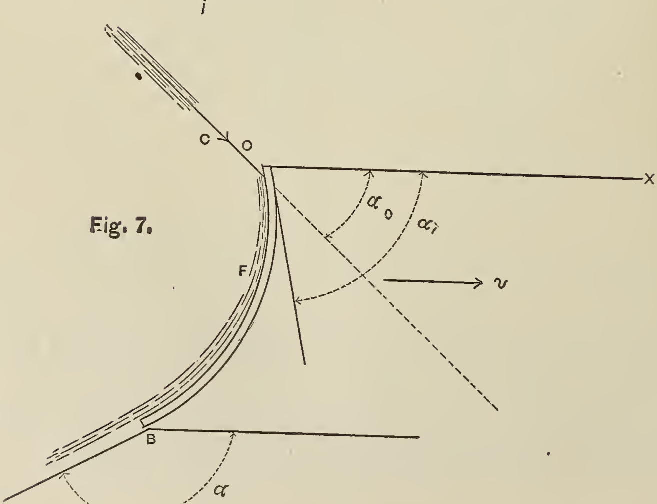


Fig. 7.

den turn, and $\frac{Q\gamma}{g}c\,[\cos\alpha_1 - \cos\alpha]$ due to the pressure of the water in contact with the arc OB; *i. e.*, as before, $P_x = \frac{Q\gamma}{g}c\,[\cos\alpha_0 - \cos\alpha]$ and the rate of work in $P_x v = \frac{Q\gamma}{g}c[\cos\alpha_0 - \cos\alpha]v$. That part of P_x due to the sudden turn might be called the effect of impulse, and the second portion the effect of reaction, following Rankine's idea; but the writer sees no ground whatever for distinguishing the nature of pressure on the arc above F (in Fig. 1, p. 249 of the March Eng. Mag. '79), where the relative deviation is gradual, from that below F where it is also gradual. The X components (see Fig. 5 of this article) of the normal pressures of elements of the stream above F, (Fig. 7) at any instant, are in the same direction as those of the elements below, while the Y components of both portions, though opposite in direction, are all nullified by the supports, which only allow a motion of the vane parallel to X.

7. Considering the vane in Fig. 7 as one of a series forming an "impact wheel," whose plane of revolution is perpendicular to the paper in that figure, we will then have, for reasons similar to those adduced in the last part of § 5, the work done per second

$$= \frac{Q_1\gamma}{g}c[\cos\alpha_0 - \cos\alpha]v,$$

where Q_1=volume of water passing the nozzle or mouth piece of the jet, per second, care being taken to place them sufficiently near, that no water escape impact.

The expression last given is identical with that derived in another way (comparison of initial, and final, kinetic energies) by Weisbach, (Vol. II. § 231).

Enough has now been presented in reference to the action of water in a vane moving parallel to itself to show what is thought by the writer to be a clearer, and more logical and rigid method of analyzing the problem than any other he is acquainted with.

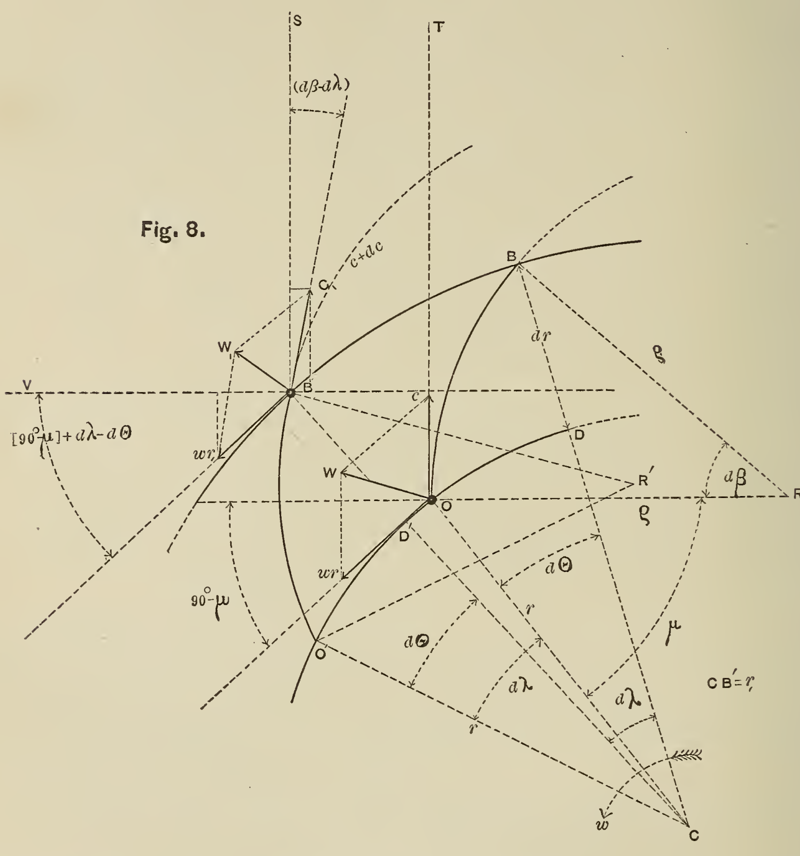
To show the application of the same analysis when the vane or channel rotates about an axis perpendicular to the plane of the water's motion, the particular case of an outward flow Fourneyron Turbine, working under certain conditions, will be considered; but as a necessary preliminary to its discussion, the following problem in mechanics needs investigation:

8. *Problem.*—Given a horizontal disk, revolving with a constant angular velocity, ω, about a vertical axis, and containing in a smooth curved channel, or groove, a particle whose mass is M, free to move without friction in the groove; required the normal pressure N, between M and the side of the groove, and also the law of variation of M's relative velocity, c, along the groove. [The last requirement is indeed solved by Weisbach (see pp. 610, 611, and 612, Coxe's translation of Vol. I.) by the employment of a fictitious centrifugal force; fictitious, because the particle in question is *not* compelled to follow the arc for whose radius and velocity that centrifugal force is computed. On p. 612, the (relative) energy stored is written $\frac{Mc_2^2}{2} - \frac{Mc_1^2}{2}$, whereas these two amounts of kinetic energy are those relative to *two different circumferences* of the top, so that their difference has no meaning, and cannot properly be said to be energy stored relatively to the top, since each circumference of the top has a different velocity. One of these faults counteracts the other, and thus a correct result is obtained].

As in a preceding paragraph, so here, we shall derive an expression for the rate of change (acceleration), consequent on supposing a slight motion of both disk and particle, of that component of the particle's absolute velocity which is in the direction of the normal (to the groove); and this acceleration (or retardation), multiplied by M, will give the normal pressure of the side of the groove against the particle, at that instant. While, to find the law of change of c, we need only write the rate of change in the tangential component (tangential to the groove) equal to zero, for no friction is considered; and from this last equation that law can be determined.

9. In Fig. 8, let C be the central axis of the disk, which is revolving with the uniform angular velocity ω, and OB an element of the arc of the groove or channel, whose radius of curvature is$=\rho$,

and whose extremities O and B, are radially distant, r and r_1, respectively, from C. Let μ= angle contained between the radii ρ and r. If, at the beginning of the instant dt (t being the independent variable), the particle is at O, having an absolute velocity w, the diagonal formed on c, its relative velocity along the groove, and ωr the velocity of rotation at that distance from the axis; then when dt has elapsed, the particle, being at B′, will have described the arc $OB = O'B' = cdt = \rho d\beta$, which subtends an angle $d\theta$ at the axis, the disk will have rotated through a small angle $d\lambda = \omega dt$, the particle is a distance dr further from the axis, and its velocity in the groove has increased to $c_1 = c + dc$, which combined with the velocity of rotation at that point, $\omega r_1 = \omega(r + dr)$ gives an absolute velocity ω_1, differing in magnitude and direction from that w, at O. If, therefore, we divide the difference of the components of w_1 and w in



the direction OR (normal to the groove at O) by dt, we have the rate of change of absolute velocity in that direction, and multiplying this by M will give N the normal pressure which must exist between the particle and the side of the channel. Hence, draw B′V parallel to RO, and B′S perpendicular to it. The component of w_1 along B′V, *i. e.*, its projection upon it will be equal to the algebraic sum of the projections of ωr_1 and c_1 upon B′V; a corresponding statement can be made concerning w.

The following relations, evident from an inspection of Fig. 8, will be referred to in subsequent work, viz:

$$OB = cdt = \rho d\beta; \text{ or, } \frac{d\beta}{dt} = \frac{c}{\rho} \quad . \quad . \quad . \quad . \quad (1)$$

$$rd\lambda = (\omega r)dt; \text{ or, } \frac{d\lambda}{dt} = \omega \quad . \quad . \quad . \quad . \quad (2)$$

$cdt \sin \mu = dv$; or, $\frac{dr}{dt} = c \sin \mu$ . . . (3)

$rd\theta = cdt \cos. \mu$; or, $\frac{rd\theta}{dt} = c \cos \mu$ . . . (4)

Formulating the above reasoning we have

$$N = M \frac{1}{dt} \left\{ \omega r \sin. \mu + c \times 0 \right.$$
$$- \left(\omega(r + dr) \cos. [(90° - \mu) + (d\lambda - d\theta)] \right.$$
$$\left. \left. - (c + dc) \sin. (d\beta - d\lambda) \right) \right\}$$

Putting for brevity's sake, $(d\lambda - d\theta) = d\gamma$ and $(d\beta - d\lambda) = d\delta$, and expanding, we have

$$N = \frac{M}{dt} \left\{ \omega r [1 - \cos d\gamma] - \omega\, dr \sin. \mu \cos d\gamma \right.$$
$$+ \omega r \cos. \mu \sin d\gamma + \omega dr \cos \mu \sin d\gamma$$
$$\left. + c \sin. d\delta + dc \sin d\delta \right\}$$

Now reject all terms containing differential factors of the second order, among which is to be reckoned $(1 - \cos d\gamma)$ $=$ vers. $\sin d\gamma$; and put $\cos d\gamma = 1$ and $\sin d\gamma = d\gamma$, etc. Whence, after restoring the values of $d\gamma$ and $d\delta$,

$$N = M \left\{ \frac{cd\beta}{dt} - \frac{cd\lambda}{dt} - \omega \frac{dr}{dt} \sin \mu \right.$$
$$\left. + \omega r \cos \mu \left(\frac{d\lambda}{dt} - \frac{d\theta}{dt} \right) \right\}$$

Or, substituting from equations (1), (2), (3), and (4), after expanding, etc.,

$$N = M \left\{ \frac{c^2}{\rho} + \omega^2 r \cos \mu \right.$$
$$\left. - \omega c [1 + \sin^2 \mu + \cos^2 \mu] \right\}$$

or, finally,

$$N = M \left\{ \frac{c^2}{\rho} + \omega^2 r \cos \mu - 2\omega c \right\} \quad \ldots\ldots (5)$$

as the value of the mutual normal pressure between the particle and the side of the channel. The reader will find it interesting to apply this formula to cases where N is known already from obvious considerations; *e. g.* when the particle has no motion relatively to the groove, and is prevented from increasing its distance from the axis by means of an obstacle at right angles to the radius vector, we have $c = 0$ $\mu = 0°$ whence

$$N = \omega^2 M r,$$

the pressure due to centrifugal force as it should be. By placing the parenthesis, in the value of N, equal to zero, we have a condition to be satisfied at every point of a channel so formed that the particle shall describe a horizontal straight line in space, as if the disk were not there.

10. To find the law of variation of c, the relative velocity of the particle, it remains to find an expression for the rate of change in that component of the particle's absolute velocity which is parallel to the tangent OT, Fig. 8, and write it equal to zero, as there is no tangential force, the groove being considered perfectly smooth. As before, we project w_1 and w upon the direction OT (or B′S), and take the difference between the two projections. Hence the rate of tangential change of absolute velocity, putting $(d\beta - d\lambda) = d\delta$, and $(d\lambda - d\theta) = d\gamma$

$$= \frac{1}{dt} \left\{ (c + dc) \cos d\delta - \omega(r + dr) \sin \right.$$
$$\left. [(90° - \mu) + d\gamma] - (c - \omega r \cos \mu] \right\}$$

$$= \frac{1}{dt} \left\{ -c(1 - \cos. d\delta) + dc \cos. d\delta + \omega r \cos \mu \right.$$
$$- \omega r \cos. \mu \cos. d\gamma - \omega r \sin. \mu \sin. d\gamma$$
$$\left. - \omega dr \cos. \mu \cos d\gamma - \omega dr \sin \mu \sin d\gamma \right\}$$

Putting $(1 - \cos d\delta) = o$, $\cos. d\delta = 1$, $\cos. d\gamma = 1$, $\sin d\gamma = d\gamma$, and rejecting $\omega dr \sin. \mu d\gamma$; *i. e.*, neglecting all terms containing as factors differentials of the second order, we have, after slight reduction the form

$$\frac{1}{dt} \left\{ dc - \omega r \sin. \mu d\gamma - \omega dr \cos \mu \right\};$$

which becomes, after restoring the value of $d\delta$ and $d\gamma$,

$$= \left\{ \frac{dc}{dt} - \omega \sin \mu \frac{rd\lambda}{dt} \right.$$
$$\left. + \omega \sin \mu \frac{rd\theta}{dt} - \frac{\omega dr}{dt} \cos \mu \right\}$$

Substituting from equations (2), (3), and (4) the last two terms disappear, and we have, imposing the condition (=zero)

$$\frac{dc}{dt} = \omega^2 r \sin \mu; \text{ or } \frac{cdc}{dt} = \omega^2 rc \sin. \mu;$$

or, finally, from equation (3),

$$cdc = \omega^2 rdr \quad \ldots\ldots (6)$$

$$\text{or} \int_{c_0}^{c} cdc = \omega^2 \int_{r_0}^{r} rdr;$$

i. e., $c^2 = \omega^2 r^2 - \omega^2 r_0^2 + c_0^2$ . . . . . (7.)

the same result as Weisbach states, on p. 612 (Coxe).

In (7.) c_0 denotes the known relative velocity of the particle and r_0 its known distance from the axis, at some previous instant, and we notice that c is *independent of the form of the path*, depending only on the distance r, from the axis, and constants.

(If a frictional resistance along the tangent, ΦN, were considered, we would obviously have

$$\frac{dc}{dt} = -\frac{\Phi \text{N}}{\text{M}} + \omega^2 r \sin\mu$$

11. To justify the application of equations (5), (6), and (7), to an outward-flow turbine wheel, we must have certain conditions realized, which are these: the wheel discharges into the air, the cross-section of the water in each of its channels diminishing from F_0 (at the inner circumference) as the relative velocity, c, grows larger, so that

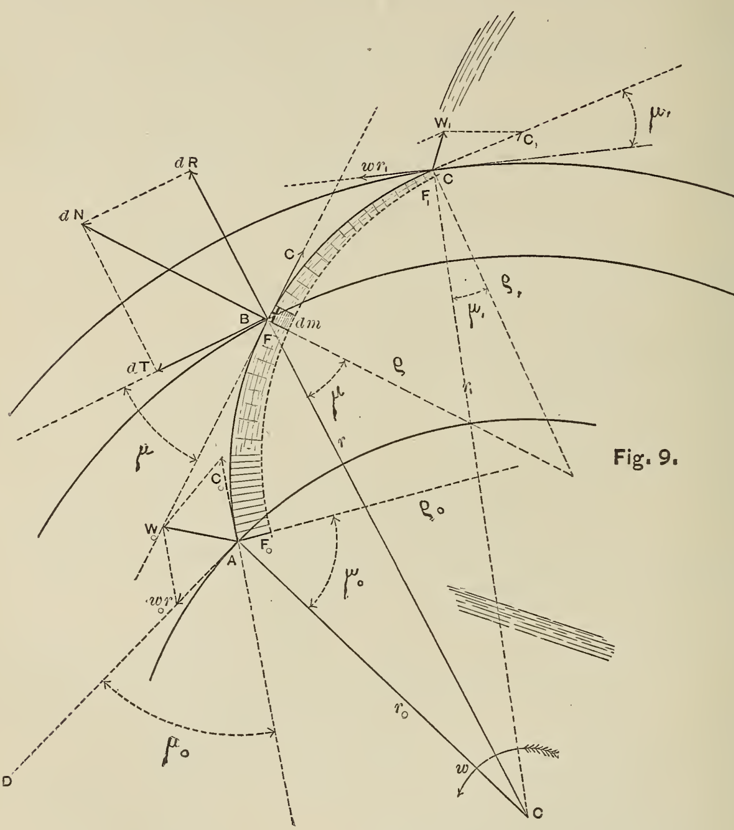


Fig. 9.

$Fc = F_0 c_0$. Also suppose the orifices of the guide channels to form a continuous series round the circumference of r_0, the inner radius of the wheel. The water is delivered from those latter stationary orifices with a known velocity w_0, upon the wheel, in a known direction (from each orifice) making the same angle with the radius at all points of the circumference of r_0. At the outset, at least, the initial relative velocity c_0, will be supposed tangential to the wheel-channel at the entrance. The wheel has a known, constant, angular velocity, ω.

Let AC, Fig. 9, be any curved float of such a wheel, revolving in a horizontal plane with an angular velocity ω, and B any point of the curved vane, or float. At any instant the whole length of the float is covered with water, whose cross-section and relative velocity at A are F_0 and c_0, the absolute velocity there being w_0, making such an angle with AD that its component c_0 shall be tangent to the float at A. At any point, as B, the cross-section is F, and relative velocity c, according to the relations, $Fc=F_0c_0$, and that expressed by eq. (7.); *i. e.*, the channels of the wheel are not supposed to be filled with water, necessarily. At any instant each dm $(=\frac{Fds\gamma}{g}$, where ds denotes an element of the arc AB$=s$) is exerting normally against the float a pressure dN, which may be replaced by two components, one dR, radial to the wheel having no part in producing motion, and dT, perpendicular to the radius vector, r, of that point, which component alone is available for aiding rotation of the wheel, its moment about the axis being$=d\text{T}r$. Therefore if there are n floats in the wheel we have the total moment of rotation, at any instant,

$$\text{M}=n\int_{\text{A}}^{\text{C}} d\text{T}r \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

We have now only to make substitutions from preceding equations, so as finally to derive, if possible, M=function of Q, γ, v_0, v_1, r_0, r_1, μ_0, μ_1 and ω.

12. Knowing that $d\text{T}=d\text{N}\sin\mu$, and substituting the value of dN from eq. (5) remembering that the N and M of that equation are the dN and dm of our present problem, we have (8) transformed into

$$\text{M}=n\int_{\text{A}}^{\text{C}} dm\left\{\frac{c^2}{\rho}+\omega^2 r\cos\mu-2\omega c\right\}\sin\mu$$

As the further reduction is rather tedious, the successive steps will be simply indicated without rewriting the equation each time.

First, substitute

$$dm=\frac{Fds\gamma}{g}=\frac{F_0c_0\gamma ds}{gc}$$

and take the constant factor $\frac{F_0c_0\gamma}{g}$ outside of the integral sign.

Secondly, substitute

$$ds=\frac{dr}{\sin\mu}=\frac{cdc}{r\omega^2\sin\mu}$$

[from Fig. 8 and equation (6)].

Thirdly, substitute

$$\rho=\frac{ds}{d\beta}=\frac{dr}{\sin\mu\, d\beta}=\frac{cdc}{r\omega^2\sin\mu\, d\beta}$$

[from Fig. 8 and equation (6)].

Fourthly, from Fig. 8 we have, after inspection,

$$d\mu=d\lambda-d\beta;\ \therefore\ d\beta=d\lambda-d\mu$$

which is to be substituted.

Fifthly, (Fig. 8) $rd\lambda=\frac{dr}{\tan\mu}$ which substitute, remembering that $\tan\mu=\frac{\sin\mu}{\cos\mu}$, and we have

$$\text{M}=\frac{nF_0c_0}{\omega^2}\cdot\frac{\gamma}{g}\int_{\text{A}}^{\text{C}}\Big\{\omega^2c\cos\mu dr$$
$$-\omega^2cr\sin\mu d\mu+\omega^2rdc\cos\mu-2\omega cdc\Big\};$$

that is,

$$\text{M}=\frac{nF_0c_0\gamma}{g}\cdot\frac{1}{\omega^2}\int_{\text{A}}^{\text{C}}\left\{\omega^2d(rc\cos\mu)-2\omega cdc\right\}$$

or, since $nF_0c_0=Q=$volume of water passing over the floats per second, which also$=Q_1$, passing through the guide channels per second, we have, after integrating $d(r\,c\cos\mu)$ between the limits $r_1c_1\cos\mu_1$ and $r_0c_0\cos\mu_0$, and cdc between c_1 and c_0,

$$\text{M}=\frac{Q\gamma}{g\omega}\Big\{c_1(\omega r_1)\cos\mu_1-c_0(\omega r_0)\cos\mu_0$$
$$-c_1^2+c_0^2\Big\}\ .\ .\ .\ (9)$$

a result independent of the shape of the float between A and C, depending only on the initial and final conditions at A and C respectively.

Consequently the work done per second is

$$\omega\text{M}=\frac{Q\gamma}{g}\Big\{c_1\omega r_1\cos\mu-c_0\omega r_0\cos\mu_0$$
$$-c_1^2+c_0^2\Big\}\ .\ .\ .\ .\ .\ .\ (10)$$

which may be easily shown to be identical with the result obtained by Weisbach's method of comparing the initial and final kinetic energies of Q_1, *i.e.*, work done on wheel per second = kinetic energy of water lost per second,

$$=\frac{Q\gamma}{g}\cdot\frac{w_0^2}{2}-\frac{Q\gamma}{g}\cdot\frac{w_1^2}{2},$$

for w_1 and w_0 are capable of expression in terms of c_1, ωr_1, μ_1, and c_0, ωr_0, μ_0, respectively.

13. If the initial absolute velocity w_0 were such in magnitude and direction that the initial relative velocity c_0 made an angle $\mu'>\mu_0$ with the wheel-tangent

AD Fig. 9, the force at A perpendicular to r_0, arising from the sudden turn, would be

$$P=\frac{Q\gamma}{g}c[\cos\mu_0-\cos\mu']$$

(just as in § 6, Fig. 7) and the work done by it per second

$$=P\omega r_0=\frac{Q\gamma}{g}[c_0\,\omega r_0\cos\mu_0-c_0\,\omega r_0\cos\mu']$$

and adding this quantity to that already obtained in equation (10) due to the gradual deviation, we have, for the case when the water arrives upon the wheel *non-tangentially*, work per second,

$$=\frac{Q\gamma}{g}[c_1\omega r_1\cos\mu_1-c_0\,\omega\, r_0\cos\mu'-c_1^{\,2}+c_0^{\,2}], \quad \ldots . \quad (11)$$

the same as if the curve of the float had been so altered at A, as to make c_0 tangential. It certainly seems that some useful energy would be lost in eddying, etc., if the water arrived non-tangentially upon the wheel. As to practical experiments, which apparently have decided a greater effect to be produced when the water enters non-tangentially, it must be remembered that to realize in one of two experiments (with the same wheel and same form of floats) a tangential entrance, in the other a non-tangential, two different angular velocities are necessary; hence proper conditions for comparison do not exist. To the writer the following would seem a fair test: after one experiment has been made with non-tangential entrance, the wheel having a certain angular velocity ω, let another be made with precisely the same conditions, velocities, etc., except *that the inner curve of the float at A be so changed that a tangential entrance is realized.* A comparison of the rates of work in the two cases can then be made with some hope of deciding the question.

14. The horizontal water-wheel so far considered has been one working in the air, not under water, with its channels not necessarily filled, unless their form is such that the stream of water whose cross section is $F=\frac{F_0c_0}{c}$ happens to be of the same form as the channel (the channel must be no smaller, however). Sufficient has been done, however, in the treatment of this case, it is thought, to verify Weisbach's method of treating turbine wheels of the Fourneyron, Jonval, and Francis type, and, especially, to give a clear idea of the pressure exerted by the water at any point of the curved vane or channel against its surface, in the cases treated in this article.

THE DANGERS OF BAD PLUMBING.

By Mr. W. EASSIE, C. E.

From "The Builder."

DURING the Exhibition which was held in Leamington in 1877, I contributed some remarkable specimens of mal-construction in plumbing, and also some curious examples of leaden pipes into which holes had been gnawed by rats while seeking ingress to a house. I also showed several pieces of sheet lead which had been completely perforated by worms that had previously destroyed the unseasoned roof boarding underneath. In the present Exhibition I have laid upon a table some still more remarkable examples of defective and dangerous plumbing; and I may add that each specimen which I exhibit has been associated with death and disaster in some shape or other. In the few remarks which I will now proceed to make, I will endeavor to classify under the heads of Imperfect Jointing and Improper Treatment of Wastes, the sources of some of the evils complained of, so that each specimen may point its moral.

IMPERFECT JOINTING.

These faults will mostly be found in soil pipes. For instance, there is the slip joint, properly so called, in which one portion of the soil pipe has simply been dropped into another, without any filling up material or solder. A necessary result of this is, that the sewer gas escapes at all times into the house, when the soil pipe has to be erected in the interior of the house in the ordinary wall chases. Even when the soil pipe had been led outside the house I have come across notable examples in which the sewer air has escaped from these open joints, and found an entrance into the house by way of the open windows. Cases of death due to this improper delivery of soil are very common indeed, and the victims are mostly servants who sleep in attics, the windows of which open above these pipes. Sometimes, even when the joints have been properly made with solder, but when the soil pipes inside the house have been insufficiently tacked to the wall or insufficiently supported, the weight of the soil pipe has sufficed, by dragging action, to open the joints, with the usual bad consequences. It is not an uncommon occurence to lay bare soil-pipe joints which have been made with putty, and tied over with canvas; or red lead joints, without the slightest attempt at soldering; and when these joints were dry an open annular seam has appeared, which has allowed an exit for the sewer air. Joints of this description are almost invariably found in the older class of houses, and I have exhibited, on several occasions, pieces of soil pipe, not more than 2 feet in length, upon which could be noticed each one of these samples of improper jointing. I need hardly say that faults of this kind are mainly attributable to the carelessness of the workman, who has been content with the worst of patching, instead of insisting upon an entire replacement of the worn-out pipe, as was his duty. I am only too well aware that very often the builder has orders from the owner to carry out the very cheapest repairs; but this ought not to be a valid excuse, because it is neither workmanlike nor business-like to treat so serious a matter as a soil pipe in this way, and he ought to know very well that a soil pipe cannot fulfill its duty properly unless it can sustain a column of water inside without trickling at the joints; and when the builder observes, upon taking down the casing, that a pipe has become eaten into holes by sewer air, or is abnormally thin, he should know that no amount of patching he can devise will remedy the defects, seen and unseen, in such a case.

The corrosion of soil pipes into holes is almost entirely due to the action of sewer gas, and will always be found present in some portion or other of an old soil pipe which has never been ventilated. Where disinfectants of certain kinds are freely used, the decay of the lead is greatly accelerated. When a soil pipe of this description is laid bare, the safest way is at once to remove it, and to replace it by a drawn lead soil pipe of proper thickness, duly ventilated by a continuation of the same diameter of pipe up to the roof, remote as possible from windows and chimneys.

There is another thing which a builder has a perfect right to refuse to do, and that is, to lead the soil from a water-closet into a rain-water pipe which descends inside the house, or has its extremity near any window. This is a very frequent cause of illness, even when such a rain-water pipe, made to do double duty, is led outside the house; as, for the most part, it will be found that the upper extremity delivers foul air perilously near the inmates. During the past year I have known cases of death traced to this very fault. The evil factor in such improper treatment is multiplied when the pipe has not been made of lead, but only of lengths of thin cast-iron down-pipe, which cannot properly be jointed or made air-tight. I say that no responsible builder should ever consent to the erection of such inadequate soil piping, or only upon the specification of an architect or engineer who dare risk it under certain conditions. Nor ought any one to make use of an iron soil pipe outside the house, unless it be thoroughly disconnected at the foot, and a current of fresh air thus continually passed through it.

IMPROPER DELIVERIES OF WASTES.

A very large percentage of the waste pipes of sinks are led direct into the drain, with only a bell trap inside the room, which is oftener than otherwise broken, or with its upper portion removed for the convenience of passing down, quicker than is needful, the pantry and other sink wastes. As a result of this, and especially in butler's rooms, where he perforce sleeps, in order to be close to the strong room, a regular highway for foul air is established into the rooms, bringing with it sicknesses of many kinds. It is the same too often with housekeepers' rooms and servants' halls, in which sinks have been placed, and servants who are often obliged to pass the greater part of the day in such rooms suffer in consequence. The only remedy against this state of things is to cause the sink to deliver over the trapping water of an open gully outside the house, no matter what distance the pipe may have to go to reach the exterior of the building, and to provide, as well, a trap underneath the sink itself, in order to keep out the cold air, and the effluvium arising from the decomposing wastes in the gully. This latter is a point which is often overlooked.

The above state of things is sufficiently bad, especially in a large household, too profusely equipped with sinks in the basement; but it is, perhaps, nothing to be compared to the improper entries of housemaids' sinks into soil pipes or D-traps of closets. In nearly every instance when a foul smell is discernible upstairs, it will be found to arise from this improper connection between these wastes and the soil system. I am not now speaking of properly constructed housemaids' sinks, with ventilated traps underneath, which are purposely constructed for the removal of bed-chamber slops of all kinds, because these may be allowed in such cases to enter a properly ventilated soil pipe; but I refer rather to sinks merely intended to remove away the drips from hot and cold water taps, in which case the danger is greatly enhanced by the sinks being placed in passages close to bedrooms, and in proximity to the great air-shafts formed by the staircases. These kinds of sinks should invariably deliver in the open air, and may sometimes be conveniently and safely led to the upper head of a rain-water pipe.

Another disgraceful system which obtains in many houses, even of very modern construction, is the leading of the cistern waste or overflow into the trap of a closet. I have this year exhibited some startling examples of this dangerous practice, and I most earnestly call attention to the fact that drinking water is contaminated in this way to an extent which must be incredible to anyone who has not made the sanitary inspection of houses his special study. I have come to the conclusion that the wisest way to avoid the dangers consequent upon this improper treatment of a cistern waste is to treat the latter as an overflow, and point it through the wall in all cases where a standing waste cannot be led to deliver in the open air.

The few remarks which I have made upon the subject of the delivery of housemaids' sinks into the D-traps and P-traps of closets are equally applicable to the wastes and overflows of baths. An examination of my pilloried specimens will show that this practice is far too common. One can observe there the traps of closets, into one of which have been led the waste of a cistern supplying drinking and closet-flushing water, the waste of the housemaid's sink, and the waste and overflow of a bath. As may be observed there also, the wastes of baths, sinks, and cisterns have been taken into both cheeks of one D-trap. It is bad enough to place the bath in the same room as a closet, and I wonder how architects can persist in this evil association, but it is something horrible to think that the delivery of the bath waste is into the very foulest conduit. And yet this latter mistake is one very constantly practiced by plumbers who at least ought to know better, and who ought to feel themselves in a position to refuse to carry out such a practice, even if ordered to do so by a clerk of works. I have known instances in which death has entered a household by way of a bath pipe thus dangerously connected, the danger being enhanced by the frequent contiguity of bath rooms to bed rooms.

Nor can it be said that these errors of judgment, or worse, apply only to old houses, for I exhibit samples of closet traps, with bath, cistern and sink entries, which are palpably but lately from the plumber's hands. In the majority of cases the excuse cannot be urged that these mistakes have been perpetrated in order to save money or to scamp the workmanship, because many of these traps are really excellent specimens of skilled labor, and in some of them the wonder is how the painstaking workman could have brought his soldering iron into play at the wiped joints in so small a space. The faults are entirely, in such instances, due to total ignorance of sanitary principles, and to a slavish following out of the traditions of the workshop.

When we come to the water closet itself, we are all bound to admit that there is a great deal still to be done in providing a faultless apparatus. Most horrible examples of death-dealing closets are to be found, especially in the area vaults of our best houses. I should, above all, like to see abolished the filthy D-trap, with its furrings of fœcal matter, the huge iron container, with its linings of ancient ordure, and the trap at the foot of the soil pipe, with its excremental cess pit. I would even like to see abolished all traps whatsoever to closets, and I am convinced that if plumbers will only follow the lead of our more advanced sanitarians in this respect, or at least more largely patronize the earthenware closets, that much solid good and absence from disease would accrue to the community. It is almost criminal for builders still to persist in the use of the pan closet, which, to my knowledge, was condemned by Mr. Chadwick nearly forty years ago, and how they can insist on fixing this dangerous contrivance without a ventilating pipe, is more than I can fairly understand. I will not believe for a moment that its use is continued in order to sell the D-trap with it, the making of which occupies the time of the apprentices, or to provide for a regularly recurring bill of repairs; but those who persist in its use lay themselves open to the charge that they are introduced for no other purpose. I think the sole reason for the patronage it obtains is to be found in ignorance, and a false estimate of its economy and cheapness of erection. And I am persuaded that if our builders would only take to heart the lessons taught by the inspection of the much better articles seen at the present day in sanitary exhibitions, they would refuse to have anything more to do with it.

There is another fault concomitant with the use of nearly all closets, and that is the leading of the waste of the tray or safe under the apparatus into the closet trap. It is almost invariably taken there in the commoner houses, and in a very large percentage also of the better class houses even yet, and one-half the smells which encounter one on entering into a closet room is due to this lamentable want of common sense and forethought in dealing with the closet essentials.

It is, perhaps, somewhat too much to expect that our tradesmen are all acquainted with the necessity for the disconnection of the house drains from the sewer by means of any of the numerous disconnection traps, constructed on various systems, now in the market. But until such a trap is provided between the house and the sewer, at some part of the house drain, the work has been only half done. Nor can there be obtained any absolute safeguard from sewer air or house-drain gas, or any thorough ventilation of the horizontal drain or vertical pipes, until some method of absolute disconnection be practised, and fresh air taken in at such a trap in order to be discharged at the ventilating pipes. No plumber, however perfect his work, can hope to witness really satisfactory results from his labor until this disconnection has been achieved.

In 1877 the German Railroad Union announced that it would award nine prizes of from $375 to $1,875, amounting in all to $7,500, for inventions of improvements made from 1872 to 1878 of the following three classes, viz., railroad construction, and apparatus used in construction, railroad equipment and its management, and railroad administration and statistics, or for important railroad publications. There were thirty-two competitors for prizes—three in the first, seventeen in the second, and twelve in the third group. In the first group a first prize, $1,875, was given for the Serres and Battig iron permanent way, and a third prize, $375, for a switch apparatus, invented by Blanel, of Breslau, which does not break the main track. In the second group a second prize of $750 for a railroad freight-car fastening, invented by Thomer & Köhazy, of Kaschau, and a third prize of $375 to Klose, a Swiss superintendent of motive power, for a speed recorder for locomotives. In the third group the only prize given was a third prize of $375 for a commentary on a criminal law of the empire which applies to railroad men.

THE TAY BRIDGE.

From "Engineering."*

The court of inquiry appointed by the Board of Trade to examine into the causes of the failure of the large spans of the Tay Bridge commenced its sittings at Dundee on January 3d. On that day the members of the court, namely, Mr. Rothery, Wreck Commissioner, Colonel Yolland, and Mr. Barlow, the President of the Institution of Civil Engineers, first proceeded to examine the ruins of the bridge from the deck of a tug steamer, and then traversed the southern standing portion, after which they returned to Dundee, and took the evidence of a number of railway officials as to the occurrences on the night of the disaster. On Monday and Tuesday of the present week, the court again sat, receiving the evidence of eye-witnesses of the failure of the bridge, and that of the divers who have been employed to explore the bed of the river, and ascertain the present state of the fallen structure, and this portion of the inquiry having been completed, the court was on Tuesday adjourned *sine die*, it being as yet unsettled whether any further evidence shall be taken at Dundee or whether the subsequent meetings of the court shall be held in London. All that at present seems to be certain is that few if any further steps will be taken until some portion of the broken girders have been raised, or it has been determined that any attempt to raise parts of the structure in such a way as to throw a light on the mode of the failure is impracticable. Under these circumstances it is probable that there may be a considerable—although perhaps not unnecessary—delay before the inquiry is proceeded with, and this being so it appears to us desirable to comment upon some of the facts of the case as far as they are at present known, while there is yet time, by a careful examination of the débris, to strengthen or disprove the conclusions towards which they seem to clearly point.

And here we may remark that the examination of the local witnesses has added little to the information which was available almost immediately after the disaster, except that the statements of the divers of course afford particulars of the position of the first part of the train and of some portions of the fallen structure. The evidence of the eye-witnesses appears to prove pretty clearly that the train was proceeding steadily on its way up to the moment when the failure of the bridge occurred, and also that the several spans which gave way did not go all at once but successively; but beyond this it proves little or nothing. From an engineering point of view the most interesting evidence yet given before the court of inquiry is that of the divers taken during the sitting on Tuesday last. The explorations of the divers have not yet been sufficiently complete to enable a clear picture to be drawn of the present condition of the fallen structure, but as far as their statements go they appear to show pretty clearly that the overturned piers have been completely broken up, that the fallen girders are lying in a fairly continuous line from north to south on the eastern side of the piers—what was the east side being now the underside—and that the train when the bridge failed was partly on the fourth and partly on the fifth span from the southern end of the gap, its center being somewhat to the north of the fourth pier. The engine is stated to be lying some 50 feet or so from the fifth pier on the south side, while the tender, two third-class carriages and one first-class are lying between the girders following south from the engine. It will be remembered that thirteen spans have given way, and in the course of the inquiry these spans, with the piers which carried them, have always been numbered from the south side, and to prevent confusion it will be desirable to adhere to this notation. From the statements of the divers it appears that there is a gap in the top boom of the girders a short distance southeast of No. 4 pier, but the information concerning the nature of this gap is not at present at all clear. Altogether the evidence of the divers, although of much interest in many respects, is yet somewhat contradictory

* Of January 9th.

on certain points, and the present condition of the girders cannot yet be spoken of with certainty. As regards the condition of the remains of the piers, no evidence has as yet been laid before the court of inquiry, but we have ourselves carefully examined them, and we shall have something to say of them further on. Acting on a suggestion of the court, we may add, the railway company are, we understand, taking steps to have the remaining bases of the piers photographed, so that a permanent record of their condition may be obtained.

We have referred in the early part of this article to certain conclusions towards which the facts so far available appear to point, and before describing the present condition of the piers, and dealing with the lesson which this condition teaches, it is desirable, for reasons given below, that we should clear the ground by pointing out briefly certain facts bearing upon the theoretical stability of the structure.

In the course of our article on this subject last week we quoted from Mr. Edgar Gilkes' paper on the Tay Bridge, read before the Cleveland Institution of Engineers in 1876, some remarks to the effect that the wind pressure required to overturn the large spans of the structure would be not less than 96 lbs. per square foot, the exposed area of a large pier being taken at 800 square feet, and that of one span and of a train being also taken at 800 square feet each. In making this quotation, we pointed out that the train would have a considerably larger exposed area than assumed, while it was not safe to consider merely the surface exposed by the windward girder, but that some allowance should be made for the insufficiently shielded surface of that to leeward. We should not have again referred to this point pending the continuation of the official inquiry had it not been that very wild statements have appeared in several papers, some unduly depreciating, and others most unaccountably enhancing the probable stability of the Tay Bridge piers, and under these circumstances, and in view of the great interest which attaches to this question, it appears to us advisable to place plainly before our readers a few data which may not only enable an approximate estimate to be formed of the stability of the piers, but may also serve to indicate the relative importance of certain information which will, we trust, in due course be brought out during the official investigation.

From the figures given by us last week it will be seen that the cluster of iron columns forming the highest piers had, including the transverse bearers for the girders at the top, a height of about 82 feet from the top of the masonry, and the center of wind pressure upon it may be taken as 41 feet above that level. In the case of the girders the center of wind pressure would be about 95 feet, and in that of the train standing on the rails, about 93 feet above the masonry level. We may accept Mr. Gilkes' estimate of the surface exposed by the pier and the windward girder, while the exposed surface of the lee girder partially shielded as it would be by the windward girder and the train, may be fairly taken as half that of the windward girder, or say 400 square feet. The area exposed by a train of a length equal to one span (and the train which was on the bridge when it failed would be about this length) would be at least 1,600 square feet, and we may take it at that amount. Under these circumstances the overturning moment exerted by a wind pressure of 1 lb. per square foot would be:

$$800 \times 41 + 1200 \times 95 + 1600 \times 93$$
$$= 32{,}800 + 114{,}000 + 148{,}800 = 295{,}600$$

foot-pounds, or about 132 foot-tons; that is to say, it would be equal to a force of 132 tons acting at a leverage of 1 foot.

Let us next consider the provision made to resist this overturning force. We explained last week that the piers which failed consisted each of a group of six cast-iron columns, four of these being 15 inches, and the remaining two 18 inches in diameter, each of the columns (both 15 inches and 18 inches) being made, in the case of the higher columns, of seven lengths 10 feet 10 inches long united by flanges. In some of the piers a less number of lengths were used. The columns were filled with Portland cement concrete, and they were braced together by horizontal and diagonal bracing, the details of which we have still to learn. The 15 inch colums were placed in pairs 12 feet apart at the bottom and 10 feet at the top in the direction of the length of the bridge, while transversely they were 9 feet 10 inches apart throughout. The 18-inch columns were placed singly, one on each side bearing near the point of the hexagonal pier of brick and masonry, their bases being 21 feet 10 inches apart from center to center transversely to the bridge and their tops 19 feet 10 inches, each column raking inwards 6 feet.

Now it is evident that there are three principal ways in which a pier constructed as we have described could fail under lateral pressure, and these are: (1) that it should turn over bodily on the base of one of the outer columns; (2) that the outer column on the lee side should yield by bending or crushing, thus enabling the pier to turn over on the bases of the adjoining pair of columns; and (3) that the bracing should fail, thus enabling the pier to turn on the bases of all the columns, the latter coming together like the leaves of a parallel ruler. These three modes of failure might of course be also partially combined, or the columns instead of giving way at their bases might fail at some point above that level. The amount of resistance to overturning in the manner first stated (presupposing that one of the outer columns was sufficiently strong to carry the load imposed upon it by that mode of failure, and that the bracing was sufficiently rigid to transmit the load to it) would be influenced by the manner in which the columns were fixed to the masonry of the pier, as unless that fixing could be relied upon the stability would depend solely upon the weight resting on the piers. Let us first estimate the stability under the latter circumstances. Taking the weight of the columns and bracing as 90 tons, that of a pair of girders at 190 tons, and that of the engine and such portion of the train as could be carried on the length of one span at 120 tons, we should have a gross load of 400 tons to be lifted before overturning could occur. This load would act at an arm equal to half the traverse base given by the outer columns, or $\frac{21 \text{ ft. } 10 \text{ in.}}{2}$=10 feet 11 inches, and it would thus have what we may call a moment of stability of $400 \times 10.92 = 4368$ foot-tons. The overturning moment due to a wind pressure of 1 lb. per square foot we have shown to be probably about 132 foot-tons, and the wind pressure, which would overturn the bridge under the conditions assumed, would thus be $\frac{4368}{132} = 33.09$—or say 33— pounds per square foot only. If the state of affairs we have just supposed existed, therefore, the overthrow of the bridge need occasion no surprise. If, on the other hand, the columns were well secured to the masonry, the resistance of the pier to overturning would be increased, for each ton of "hold" (as we may call it) of the windward column would increase the moment of stability by 21.84 foot-tons, and the hold of the other columns proportionately to the distances of their points of attachment from the base of the column on which overturning of the structure is assumed to occur. A contemporary of ours in some singular calculations published last week, has assumed that the three windward columns could exert a pull equal to 140 tons, but in making this statement it has apparently been forgotten that for this pull to be exerted it would be necessary for the fastenings of these columns to be such that they could directly lift some 2,500 cubic feet or so of brickwork and masonry—a matter for which, at any rate, there was no provision made in the present case. As to the manner in which the fastening down of the columns was really carried out we shall speak hereafter, for the present we shall merely consider the effect of such a moderate amount of holding power as could probably be obtained under the actual conditions.

Assuming then at each of the columns was so bolted down that it could not be lifted without carrying with it between 60 and 70 cubic feet, or, say, 5 tons of stonework, and still dealing with the assumption that it was possible for the whole pier to turn over on the base of the leeward column as a center, we have an addition to the righting moment above calculated of $5 \times 21.84 + 2 \times 5 \times 15.84 + 2 \times 5 \times 6 = 109.2 + 158.4 + 60 = 327.6$ foot-tons. Adding this to the 4368 foot-tons before obtained, we get a total of 4695.6 foot-tons, and dividing this by 132 as before, we get 35.6 lb. per square foot as the wind pressure which would under these conditions just balance the stability of the structure. We may here remark that although we have deemed it desirable to show what the probable stability of the structure would be if the outer columns were of such strength and the bracing so rigid as to render the overturning of the whole structure on the base of one of these outer columns a possibility, yet we by no means admit that possibility in the present instance. In fact the calculations above given are useful chiefly as showing the amount of stability which with the weights assumed might be approached but never reached in such a structure as that with which we are now dealing. It is important to bear this fact in mind. Of course if the weights of a pier and its load were greater or less than we have assumed them to be, the maximum stability possible would be proportionately affected, and any correction due to this cause can be readily applied when the facts come out before the court of inquiry.

Next as to the second mode of failure above stated. In this case also the nature of the fixing of the columns to the masonry materially affects the question. If this fixing down be disregarded, and the stability of the piers be assumed to depend upon the insistent weight only, and if the metal of these outer columns be taken at $1\frac{1}{4}$ inches thick,* giving a sectional area of 66 sqare inches, then from the figures already given the compressive strain on the column will be $\frac{132}{66\times 10.92}=0.183$ ton per square inch for each pound of wind pressure per square foot exerted on the structure. Thus a wind pressure of 30 lbs. per square foot would induce a compressive strain in the outer column to leeward of $5\frac{1}{2}$ tons per square inch, if it be assumed that the character of the bracing were such as to enable the whole work of maintaining the pier upright to be thrown on that column. If, on the other hand, this task be assumed to be distributed between the three lee columns, the strain would be (taking the sectional area of each 15-inch column at 54 square inches, and their distance from center of pier as 4.92 feet): $\frac{132}{66\times 10.92+54\times 2\times 4.92}=0.105$ ton per square inch for each pound of wind pressure per square foot. With the compression distributed between the three leeward columns, however, the righting moment of the pier would, in consequence of the reduction in the effective transverse width of base, be much under that required to resist a wind pressure of 30 lbs. per square foot, and the maximum strain in the lee columns possible without any bolting down of the windward columns would therefore be, as we shall show directly, considerably less than the maximum which with sufficiently rigid bracing it would be possible to throw on the single outer column. Whether or not such long columns would resist the loads which might under the assumed conditions be imposed upon them would evidently depend entirely upon the manner in which their several component lengths were fitted together and upon the efficiency of the bracing to resist lateral bending, both points upon which evidence has yet to be forthcoming. We may remark, however, that the assumption that it would be possible for the compressive strains per square inch on the lee side columns to be equally distributed is an extremely favorable one, and one scarcely likely to be realized in practice.

If the fastening down of the columns to the masonry be in the first place assumed to be of no value, then it is evident that the maximum compressive strain which could be thrown upon the lee columns would be equal to the whole weight of the pier and its insistant load, or 400 tons, as we have taken it. Distributed between the three lee columns this would give a strain on the sectional areas above given of $\frac{400}{66+54+54}=2.3$ tons per square inch, or of $\frac{400}{66}=6$ tons per square inch on the outer column, if it be assumed to be possible for that column to carry the whole load. If, on the other hand, the fastening of the columns to the masonry of the pier be taken into account the compressions on the lee columns will be in no way affected until the maximum possible loads without fastenings have been reached, but beyond this point the compressive loads on the lee columns will equal these maximum loads, just stated, plus the tensile

* This appears to be the average thickness of all the columns, although there is some slight variation in the dimensions of the remains of those which we have measured.

strains on the windward columns. It will thus be seen that the fastening down of the columns to the masonry in no way relieves the compressive strain on the lee columns as a whole, although it facilitates the distribution of the strain between them, and of course augments the resistance of the pier to overturning. We have already shown that assuming the piers to have failed in the manner first stated and the columns not to be bolted down, the overturning moment required would be about 4368 foot-tons (this being the moment given by a wind pressure of a little over 33 lbs. per square foot); and to further explain the point with which we are now dealing, it will perhaps be worth while to calculate to what the extent the stability would be modified if the columns are bolted down and the compressive strain on the lee side be assumed to be equally distributed over the three columns, instead of being borne by the outer one only. In the case we are now considering, the windward and leeward groups of columns may be regarded as forming the booms of a vertical girder, and the horizontal distance between the centers of gravity of the sectional areas of these booms will, in the case of the Tay Bridge piers, be almost exactly 14.4 feet. For reasons which we shall explain hereafter, it would probably be scarcely fair to assume that the tensile strain, which each windward column could be expected to stand without disturbing the stonework, would exceed 5 tons, and taking it at that amount we have $5 \times 3 \times 14.4 = 216$ foot-tons as the moment of stability due to the bolting down of the windward columns in the case we are now considering. In this case also the superincumbent weight of 400 tons will act at an arm of $\frac{14.4'}{2} = 7.2$ feet, and the moment of stability given by it will thus amount to $400 + 7.2 = 2880$ foot-tons. Adding to this the 216 foot-tons above obtained we get a total of 3096 foot-tons, which divided by 132 foot-tons (the overturning moment due to a wind pressure of 1 lb. per square foot) gives $\frac{3096}{132} = 23\frac{1}{2}$ lbs. per square foot only as the wind pressure which would balance the stability of the pier under the conditions assumed. In this case the load on the group of three leeward columns would equal the load on the pier, plus the tensional strain on the windward columns, or $400 + 15 = 415$ tons, and as the combined sectional area of the three columns is 174 square inches the compression would be $\frac{415}{174} = 2.39$ tons per square inch. It will be seen from the figures just given how greatly the stability of the structure is impaired, if it be considered that the conditions were such as to cause the three leeward columns to share the compressive strain due to the action of the wind equally between them, instead of the outer column alone taking the major share of the work.

We now come to the third mode in which the pier might have given way, namely, by a failure of the bracing between the columns, and although it would be idle to attempt, in the absence of trustworthy information as to the details of this bracing, to form a quantitative estimate of the strength of this part of the structure, yet it is advisable to say a few words as to the light thrown upon this point by the calculations we have already given. If we assume that the destruction of the bridge was caused by a failure of the piers—and with the evidence now available it is difficult to arrive at any other conclusion—it must then be conceded that these piers would fail at their weakest part, and as we have shown that the piers could probably be overturned as a whole under the most favorable conditions by a wind pressure of about $35\frac{1}{2}$ lbs. per square foot, it follows that if the capsizing of the structure took place owing to the failure of the bracing, it took place under the influence of a wind pressure less than this. How much less, it is of course impossible to say in the absence of precise particulars of the bracing and of the mode of erection. To the information which these particulars will afford we look forward with great interest—an interest which will be shared by a large number of our readers—for, as will be seen from the notes which we give below, the remains of the fallen piers afford strong reasons for supposing that it was through a failure of the bracing that the overturning of the piers occurred. We have now arrived at the point at which it is desirable to give an account, as far as we can, of the remains of the broken structure.

From the evidence given before the court of inquiry on Monday last by Mr. Roberts, the locomotive superintendent at Dundee—who, it will be remembered, explored the northern portion of the bridge on the night of the accident—it appears that the end of the northern portion of the structure now standing remains in practically the same condition it was immediately after the failure of the large spans occurred. Let us describe what that condition is, dealing first with the aspect of the structure from above on the north side. Standing at the southern end of the northern portion of the bridge, and looking down, the columns of the terminal pier are seen to be all standing, with the tie-rods all right except on the southern face, where they are adrift, owing to the lugs of the columns on that face being mostly broken off. None of the tie-rods are broken, but only the cast iron crosses and the lugs. There seems to have been absolutely no connection between the portion of the bridge which has been carried away and the standing portion except the rails and the gas pipe handrail. The 9-inch by 3-inch flooring planks butted at the edge of the crossbeam at this point.

The ends of the girders of the large span lay on a kind of shelf on the ends of the shore span girders, and apparently without any bolting. The girders of the large span seem to have slipped off sideways at this point, and when the inner edge of the eastern girder reached the edge, the piece of the shelf broke downwards, but not off, showing apparently that the girder had a large horizontal component in the direction of its motion, and that its motion sideways was probably rapid. The western girder, on the other hand, seems to have struck at the point marked B on the sketch, and to have dropped down, clearing away in its fall a light crossbeam between B and C, which light crossbeam is now lying immediately underneath at the base of the pier. The end of the girder in falling broke away the tie-rod fastenings, crosses and lugs, as has been already mentioned. The guard rails at the north end project about 9 feet beyond the standing portion of the structure, and the projecting portions are considerably curved towards the east. The other rails are carried away from a point a short distance within the end of the standing portion of the bridge. We shall have more to say about this northern end of the bridge hereafter when speaking of the bracing.

In the case of the end of the portion of the bridge left standing on the southern side of the river, the guard rails are seen, on looking up, to be bent over obliquely to the east. The two ordinary rails each project nearly straight for about 3 feet, but the piece on the western side carries fishplates, and these are bent to the eastward nearly to the same rake as the guard rails. The top shelf pieces are not damaged apparently, but the light cross-beam in front is lying below as in the case of the pier at the northern side.

An examination of the wreck at the bridge at this point indicates strongly the probable order of the steps in the failure of the structure. The now standing pier columns at the south end of the gap are but little injured. Remembering that the six columns form a hexagon, with the north and south sides longer than the others, and that the adjacent columns are braced together with horizontal bars and diagonals, and that there are also cross sets of bars, making altogether eight planes of bracing, we may, by noting which of the parts of the bracing have given way in the various standing columns, see clearly how the bridge has failed. In the south end standing pier each column consists of six lengths. The face lying east and west on the north side of the pier—that is facing the gap—shows the three upper pairs of diagonals adrift, and the first and second double horizontal ties also detached, all of these by the fracture of the cast-iron snugs. The fourth diagonal from top east corner is also detached, as are also all the horizontal round diagonal ties; the cast-iron corner brackets, to which these latter have been fastened, have in almost every case been pulled away, breaking their flanges. The rest of this pier structure is apparently uninjured. This is the last standing pier over which the train passed.

Returning now to the standing pier at

the north end of the gap, we find a much greater damage, the effect of the straining, and a fairly clear proof that the diagonal bracing had given way, at all events partially, some time before the last wrench occurred which brought down the bridge. In our description the sloping diagonals will be denoted as ties or struts, according as they would be in tension or in compression when the top of the structure was moved to the east, that is, as the bridge fell. The diagonals were, of course, valueless as struts, and the name is only here given to them to facilitate the explanation of affairs. Looking north at the south face of this pier, which has five tiers of columns, we see that all the bracing and the horizontal bars are away on this face, except the lowest tier of horizontal bars. There are four of the strut diagonals hanging, the tension ones and their cast-iron snugs are all away.

On the north face all the struts are intact, and also all the horizontal compression bars; but all except the lowest one of the tension diagonals are detached by fracture of the cast-iron snugs to which their lower ends were attached. The horizontal bars, and some of the diagonals in the south face, have been carried away by falling débris. Still, at the same pier, on the south-east face, the top tier has both diagonals, those of the next two tiers are hanging, the next compression bar and both diagonals are gone, and the lowest tie is hanging, so that only one of the tension diagonals is here. The north-west, and south-west, and north-east faces have all their diagonals and bars intact, except the second tie from the top on the north-east face. The diagonals are of flat iron single, $4\frac{1}{2}$ inches by $\frac{1}{2}$ inch, with cottered fishplates on their lower ends, and attached to the cast-iron columns close to the flanges by one $1\frac{1}{8}$ inch bolt in a hole $1\frac{3}{8}$ inch in diameter. If the bolts had fitted the holes, then any slackness of these ties would have been seen as bending of the struts, but they may have been slack, or not all tight, and nothing would be shown wrong. The horizontal double bars are of pairs of channel irons $6\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{1}{2}$ inch, placed back to back $2\frac{1}{2}$ inches apart. There are also horizontal round bars placed diagonally between the four 15 inch columns; the cast-iron attachment of these seems to have been an afterthought, it is at least not a very well planned attachment.

The evidence of the working of the columns is abundant on this pier. The east column is cracked from north round by east to west by north, and the bolts of broken part on north-east column, at base are broken from north by west to east. The south bolt of this flange has shorn across at the joint of the flanges at the base. The north-west column is broken from west round by north to east. These breaks are all at the lower flange. The west by south bolt here has broken by tension at $\frac{1}{2}$ inch from top of column flange, the bolt is $1\frac{1}{4}$ inch, and there are, as we shall explain hereafter, eight of these bolts in each flange. The west point column has not cracked at the joint, but the two stones to which the base is bolted have been moving, and the cake of cement about 1 inch thick is broken, showing the lower end of bolt holes through the cast-iron bases and continued through the two top courses of coping stone—the only bolts in the stone foundation. The south-west column is intact, except where the snugs for diagonals are broken off. The south column is broken across at the bottom from north-east, round by east to west, and the whole column has shifted $\frac{3}{8}$ inch towards the east. The second tier of columns has at the top a provision for some other kind of fastening. On each column the snug for the braces is continued down as a rib about 3 feet, and there are eight additional holes in it, but it seems none of these have been used.

Looking up now at the top of these columns, we observe that the three on the east have practically no connection with the three on the west, and even each of the sets of three is not at the top concentrated to one position. The caps are of riveted structure in the form of a capital A laid on its flat on the three columns; the bar of the A projects a little over, and forms the shelf for the girder end. As there is a distance of about 5 feet transversely between the centers of the tops of the columns, a slight inclination of this cap will permit the sloping outer column to move out to be vertical. It is said to be 1 foot inclined now, but taking the height at only 60 feet, a rise of but one-tenth of an inch is all the sloping column requires in moving the vertical position, and as the other columns would be going down hill at the same time that the sloping column was rising, there would be only the stiffness of the columns to prevent lateral displacement, and gravity would be neutral.

From the appearance of the wreck one can certainly gather no confidence in the combined action of the diagonal ties. They may have gone, first that one which happened to be tightest, and the others to follow. The bridge has been expected to practically sit still by gravity, but the diagonal ties seem to us to have been very poor assistance to stability in this case, and an inspection of the pieces leaves the impression that when the train came on the high girders many of the ties may have been already detached, and perhaps some of the columns cracked at No. 5 pier, where the girders were not connected, and where the swaying of the girders by the wind would be greatest. The condition of this pier, and likewise of No. 9, where the girders were also not attached, we shall describe further on.

We now come to the condition of the piers which carried the fallen spans, and in describing these we shall commence from the south side, and give the piers the numbers by which, as we have already mentioned, they have hitherto been indicated in the evidence given before the court of inquiry, the pier at the northern end of the most southerly fallen span being called the first pier and so on. It will be remembered that these piers are of brickwork up to about high water level, but that above this is a stone capping of four courses of masonry of the aggregate thickness of about 5 feet. This being premised we will describe the present condition of the piers in regular order.

On pier No. 1 two lengths of the columns are standing with their tie-rods and foundation plates, the columns being almost intact. In the case of the eastern and south-eastern columns, the tops and a few inches of the columns themselves are broken off. On the north and the south faces all the tie diagonals are detached, the east column is broken at foot on south-west face, one tie diagonal stands, all the other diagonals there are detached. On the other three faces, those towards the north, all the diagonals are intact, except one tie. And here we may explain that each column springs from a foundation plate bolted to the masonry, and to which the column is itself bolted by eight bolts, these bolts being, for the 15 inch columns, $1\frac{1}{8}$ inch in diameter. In the case of the 18 inch outer columns the foundation plates are 4 feet square, while for the 15 inch columns they are 3 feet 10 inches in diameter, by $1\frac{3}{4}$ inch thick. Each foundation plate carries a socket or base about $22\frac{1}{2}$ inches high, the socket being stiffened by eight radial ribs. Four of the radial ribs first mentioned are bossed, to allow of the passage through them of the $1\frac{3}{4}$ inch bolts securing the foundation plates to the masonry, while in the case of two others, provision is made for the attachment of the bracing. The columns average, as we have already stated, $1\frac{1}{4}$ inch in thickness, and their flanges are of about the same thickness, those of the 15 inch columns being 23 inches, and those of the 18 inch columns 27 inches in diameter. The lengths of the columns have also male and female ends. With these preliminary remarks we may now continue our notes on the state of the remains of the fallen piers.

On pier No. 2 the six foundation plates are all right with some portions of the columns on the eastern side, but all above is gone. Portions of three of the columns are lying on the pier.

On pier No. 3 the foundation plates are in place, and one length of column stands, but the tops of these portions of the columns are gone. The stone work is all good.

On pier No. 4 the foundation plates are also all right with portions of the six columns attached, and hanging over on the *west* side. This would appear to indicate that this pier failed at some height above the masonry, the lower lengths of the columns being pushed over in the opposite direction to that in which the chief mass fell.

In the case of the piers so far mentioned, no stonework is out of place, but at about one-fourth of the adjacent span south of the fifth pier the engine is lying, and on this pier, No. 5, the stonework has been displaced. It will be remembered that the thirteen spans which fell, consisted of three continuous groups, the most southerly group consisting of five spans, and the two more northerly groups of four spans each. The junctions of the groups thus occurred on piers No. 5 and No. 9, and it is perhaps not without significance that in the case of these two piers the stonework is exceptionally injured.

Mounting on the masonry it is seen that all the first tier of columns is lying inclined, the stone at the west corner being lifted and still attached to the column base, but the column itself being broken off. Only the two stones at the west corner are displaced here, the others not being disturbed, and the foundation plates being fast to the stones.

On pier No. 6 the foundation plates are all good, but the columns have broken through the flanges or bolts. It may be remarked here that the cement concrete with which the columns were filled appears to be as hard as stone. We mention this because reports to the contrary have been circulated.

On pier No. 7 the foundation plates are all good, but some of the columns have broken off through the flange. Five columns are lying about the pier. In the case of pier No. 8, the stonework is all sound, and the foundation plates are intact. The first tier of columns are hanging about the pier.

On pier No. 9 the stonework has gone in the same manner as on No. 5, but worse. That is, the angle stones on the western side have lifted from their beds, but they are still on the pier. The stonework on the southern side of the pier is also shaken, the brickwork, however, being intact. The columns have in this case evidently lifted the stones. The first length of the western and south-west columns are lying canted over with their bases and two upper courses (the third and fourth) of stones attached, the stones lying on edge and showing the bottom of the third course. The dowel bolts tying the upper courses of stone together do not come through. In the case of the south-west column, the fourth course stone and a half of the third course is split through a dowel bolt hole, showing the thickened lower end of the bolt about $1\frac{1}{2}$ inch short of being through the third course of stone. This case seems to fairly represent the fastenings of the stones throughout, the dowel bolts only passing through the two upper courses, and there being no connection—beyond that given by the cement—between these upper courses and the first and second courses below them. It is this mode of fixing which has led us to place such a low limit in our calculations on the amount of tensile strain which the windward columns might be expected to withstand. The bolts by which the foundation plates are secured—and which are not the dowel bolts—appear to enter the top course of stones only; but on this point we cannot speak positively. The bolts by which the foundation plates are fixed, however, have in no case failed, all the bases on all the piers, so far as they can be seen, appearing to be firmly attached to the top course stone. In the few cases where the foundation plates are absent the stones have gone with them.

On pier No. 10 the stonework is very little disturbed. At the western corner there are cracks, but they do not extend through the stonework. The bases of the columns are here all intact, and on every one of them is a piece of the flange of the corresponding column, all these fragments being portions of the western side of the flanges. Some of the fragments include two bolt holes, and are broken through the next two bolt holes, while others similarly broken include one bolt hole only. On the base of the south-west column stands a portion of the neck of the column about 3 inches high on the western and 9 inches on the eastern side. The lower connections between the bases of the columns are here also intact, except that one pair of tie-rods on the eastern side have been bent by the columns falling on them. Three lengths of columns lie on this pier overturned towards the eastern side.

In the case of pier No. 11, the stonework has suffered considerable injury, and the remains of the columns are lying about unevenly with ends of the tie-rods attached. Towards the northern side of the pier all the stonework is intact, and three foundation plates remain fixed in position. The other foundation plates have been carried away with the stones to which they were fixed.

Lastly, on No. 12 pier the west corner or cut-water stone of the upper course—a stone about 4 feet square—is gone, and the stone below it, which measures about 6 feet by 6 feet 6 inches, is broken through the bolt holes. The bolts have gone through the two top courses only. With the exception of the foundation plate at the western corner, which has gone with its stone, the bases of the columns are all in position. There are four lengths of columns lying on this pier, and judging from their position, the canting over of the structure has first been towards the east, but in falling it has got set back towards the west. The column at the north-east corner has got canted round about 90°, and it is now standing nearly upright, but resting only on three bent tie-rods. It is somewhat dangerous moving about it. From what we have stated it will be seen that altogether the piers at the northern end of the fallen length of the bridge are in a worse condition than those towards the southern end.

We have now laid before our readers the facts connected with the failure of the Tay Bridge as far as they are at present known to us; and in bringing this somewhat lengthy article to a conclusion, we have but few remarks to add. It would be hazardous at this early state of the inquiry to urge strongly any view as to the precise manner in which the breakdown of the structure occurred; but the facts so far ascertained certainly point prominently to certain conclusions which we have indicated generally in the course of the foregoing article. On the question as to the amount of stability which the structure actually possessed, we have no desire to enlarge further on the present occasion; but the calculations we have given, together with the facts we have collated, certainly show that there is every reason to believe that it was vastly below the amount usually considered to be necessary for such works, both in this country and abroad. This, however, is a point to which the attention of the court of inquiry is certain to be prominently directed, and in taking leave of the subject for the present, we can only express a hope that the inquiry may be so conducted as to thoroughly sift all doubtful features in the design of the bridge, and to do away with the chance of any similar failure occuring in this country.

ON THE SHAPE AND SIZE OF THE EARTH.*

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Contributed to Van Nostrand's Magazine.

III.—The Earth as an Ellipsoid.

Just as the sphere is a particular case of the spheroid of revolution, so the spheroid is a particular case of the ellipsoid. The sphere is determined by one dimension, its radius; the spheroid by two, its polar and equatorial diameters; while in the ellipsoid there are three unequal principal axes at right angles to each other which establish its form and size. Like the spheroid the ellipsoid has all its meridian sections ellipses, but the equator instead of being a circle is an ellipse of slight eccentricity and its two axes, together with the polar axis of rotation, constitute the three principal diameters. Let a_1 and a_2 denote the greatest and the least semi-diameters of the equator of the ellipsoid and b the semi-polar diameter. The ellipticity of the greatest meridian ellipse is then

$$f_1=\frac{a_1-b}{a_1}$$

and that of the least is

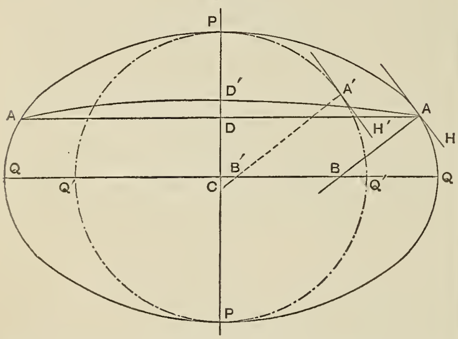
$$f_2=\frac{a_2-b}{a_2}$$

while the ellipticities of all the other meridian ellipses have values intermediate between f_1 and f_2. For the equator the ellipticity is $\frac{a_1-a_2}{a_1}$. When the values of a_1, a_2, and b are known, the dimensions and proportions of the meridian ellipses and of all other sections of the ellipsoid can be easily found. In such a figure,

* Three lectures originally prepared for the Civil Engineering Students of Lehigh University, as introductory to a course in Geodesy.

however, the curves of latitude, with the exception of the equator, are not plane curves, and hence cannot be called parallels; this results from the definition of latitude and may be seen from the following diagram. PP is the polar axis, PQPQ the greatest meridian section of the ellipsoid, and A a place of observation upon it, whose horizon is AH and latitude ABQ, AB being the direction of the plumb line at A, which of course is perpendicular to the tangent horizon line AH. Let now the least meridian ellipse, projected in the line PP, be conceived to revolve around PP until it coincides with the plane PQPQ and becomes seen as PQ′PQ′. To find upon it a point A′ that shall have the same latitude as A, it is only necessary to draw a tangent A′H′ parallel to AH touching the ellipse at A′, then A′B′ perpendicular to A′H′ makes

Fig. 8.



the same angle with the plane of the equator QQ as does AB. If the least meridian section be now revolved back to its true position A′ becomes projected at D′. We thus see that while a section through A parallel to the equator is an ellipse ADA, the curve joining the points having the same latitude as A is not a plane curve but a tortuous line AD′A.

The process for determining from meridian arcs an ellipsoid to represent the figure of the earth does not differ in its fundamental idea from that explained in the last lecture for the spheroid. The normal to the ellipsoid at any point will usually differ slightly from the actual vertical as indicated by the plumb line, and these deviations are taken as the residual errors to be equalized by the method of least squares. An expression for the difference of these deviations at two stations on the same meridian arc is first deduced in terms of four unknown qualities, three being the semi-axes a_1, a_2 and b, or suitable functions of them, and the fourth the longitude of the greatest meridian ellipse referred to a standard meridian such as that of Greenwich; and in terms of four known quantities, the observed linear distance between the two stations, their latitude and the longitude of the arc itself. Selecting now one station in each meridian arc as a point of reference, we write for that arc as many equations as there are latitude stations, inserting the numerical values of the observed quantities. These equations will contain four more unknown letters than there are meridian arcs, and from them by the method of least squares as many normal equations are to be deduced as there are unknown quantities, and the solution of these will furnish the most probable values of the semi-axes a_1, a_2 and b with the longitude of the extremity of a_1, and also the probable plumb-line deviations at the standard reference stations. The process is long and tedious, but it is easy to arrange a system and schedule, so that, starting with the data, computers may execute most of the labor, who have no idea at all of the whys and wherefores involved.

The first deduction of an ellipsoid to represent the figure of the earth was made in Russia, by Schubert, about the year 1859. His data consisted of eight meridian arcs, the Russian, English, Prussian, French, Pennsylvanian, Indian, Peruvian and South African, embracing in total an amplitude of about 72°. These were combined in a manner different and less satisfactory than that above described, the results, according to Listing, being,

$a_1 =$ 6 378 556 meters.
$a_2 =$ 6 377 837 "
$b =$ 6 356 719 "

$q_1 =$ 10 002 263 " $f_1 = \frac{1}{292.1}$

$q_2 =$ 10 001 707 " $f_2 = \frac{1}{302.0}$

$Q =$ 10 018 849 " $F = \frac{1}{8881}$

Long. of $q_1 = 40° \ 37'$ E. of Greenwich.

Here q_1 and q_2 are the quadrants of the greatest and least meridian ellipses, Q the quadrant of the equator, and f_1,

f_2 and F the corresponding ellipticities; a_1 and a_2 are the equatorial semi-axes and b the polar semi-axis. By referring to a map of the earth you will see that the maximum meridian ellipse passes through Russia and Arabia in the eastern continent and through Alaska and the Sandwich Islands in the western, while the minimum ellipse cuts Japan, Australia, Greenland and South America.

It is, however, Clarke, of the British Ordnance Survey, to whom we owe almost all our knowledge of the dimensions of the earth as an ellipsoid. His first investigation was made in 1860 and embraced the data from the Russian, English, French, Indian, Peruvian and South African arcs, in all more than five-sixths of a quadrant and containing 40 latitude stations. This calculation was revised in 1866 on account of slight changes in the data due to a careful comparison of the different standards of measure, and gave the following results as the most probable elements of the spheroid:

$a_1 =$ 6 378 294 mtrs = 20 926 350 Eng. ft.
$a_2 =$ 6 376 350 " = 20 919 972 "
$b =$ 6 356 068 " = 20 853 429 "

$q_1 =$ 10 001 553 " $f_1 = \frac{1}{287.0}$

$q_2 =$ 10 000 024 " $f_2 = \frac{1}{314.4}$

Q = 10 017 475 " $F = \frac{1}{3281}$

Long. of $q_1 = 15° 34'$ East.

The equator is here more elliptical than in Schubert's ellipsoid while the greatest meridian lies 25° farther west, passing through Scandinavia, Germany, Italy, Africa, the Pacific Ocean and Behrings Straits. The least meridian coincides nearly with that of Washington. The data entering these elements are the same as for the Clarke spheroid of 1866; in fact, by a slight change in the equations, equivalent to making $a_1 = a_2 = a$, the ellipsoid may be rendered a spheroid, and the elements of the latter also deduced.

In 1878, Clarke published the results of a third discussion in which the above-described data were augmented by a new meridian arc of 20° in India and by several arcs of longitude. The solution of 51 equations gave the following:

$a_1 =$ 6 378 209 meters = 20 926 629 feet
$a_2 =$ 6 376 202 " = 20 925 105 "
$b =$ 6 356 076 " = 20 854 477 "

$q_1 =$ 10 001 867 " $f_1 = \frac{1}{290}$

$q_2 =$ 10 001 507 " $f_2 = \frac{1}{296.3}$

Q = 10 018 770 " $F = \frac{1}{13706}$

Long. of $q_1 = 8° 15'$ West.

The equator is here less elliptical. The greatest meridian passes through Ireland, Western Africa, between Australia and New Zealand and through Alaska, while the least meridian passes through Central Asia and Central North America.

At the present time it seems to be the prevailing opinion that satisfactory elements of an ellipsoid to represent the earth cannot be obtained, until geodetic surveys shall have furnished more and better data than are now available, and particularly data from arcs of longitude. The ellipticities of the meridians differ so slightly that measurements in their direction alone will, probably, be insufficient to determine, with much precision, the form of the equator and parallels. In Europe, several longitude arcs will soon be available, and, perhaps, fifty years hence the primary triangulation of our Coast and Geodetic Survey may extend from the Atlantic to the Pacific. If it then be thought desirable to represent the earth by an ellipsoid with three unequal axes rather than by a spheroid, its elements can be determined with some satisfaction. At present the ellipsoids represent the figure of the earth as a whole very little better than do the spheroids, although, for certain small portions, they may have a closer accordance. For instance, the average probable error of a plumb line deviation from the normals to the Clarke ellipsoid of 1866 is 1″.35, while for the spheroid derived from the same data it is 1″.42. Further, the marked differences in the ellipticities of the equator of the two Clarke ellipsoids, due to comparatively slight differences in data, are not pleasant to observe. And, lastly, the ellipsoid is a more inconvenient figure to use in calculations than the spheroid. For these reasons the earth has not yet been regarded as an ellipsoid in practical engineering computations, and it is not probable that it will be for a very long time to come.

IV.—The Earth as an Ovaloid.

In a spherical, spheroidal or ellipsoidal earth the northern and southern hemispheres are symmetrical, that is to say, a plane parallel to the equator, at any south latitude, cuts from the earth a figure exactly equal and similar to that made by such a plane at the same north latitude. The reasons for assuming this symmetry seem to have been three: first, a conviction that a homogeneous fluid globe, and hence perhaps the surface of the waters of the earth, must assume such a form under the action of the forces of gravity and centripity; secondly, ignorance and doubt of any causes that would tend to make the hemispheres unequal; and thirdly, an inclination to adopt the simplest figure so that the labor of investigation and calculation might be rendered as easy as possible. The first of these is perhaps an excellent reason, considered by itself alone, but when we begin to speculate about the probability of any regular law in the density of the earth, and further when we find plumb-line deviations only to be reconciled on supposition of non-homogeniety, it seems to assume more the nature of a rough analogy. The last is a perfectly proper reason when viewed from an engineering point of view, for where practical calculations are to be made they should be so conducted that the desired results may be obtained at a minimum cost; and this argument will always, more or less, affect even the most abstruse scientists in whose investigations there is perhaps no thought of practical utility. The second reason is not so valid to-day as it was a century ago, for gradually there have come into men's minds a great many thoughts which now lead us to suppose that there are several causes that tend to make the southern hemisphere greater than the northern. These thoughts embrace a vast field of inquiry and speculation in astronomy, physics and geology; but we can here only briefly hint at two or three of the principal facts and conclusions.

The earth moves each year in an ellipse, the sun being in one of the foci, and revolves each day about an axis, inclined some $66\frac{1}{2}°$ to the plane of that orbit. When this axis is perpendicular to a line drawn from the center of the sun to that of the earth occur the vernal and autumnal equinoxes, and at points equally removed from these are the summer and winter solstices. For many centuries the earth's orbit has been so situated in the ecliptic plane, that the perihelion, or nearest point to the sun, has nearly coincided with the winter solstice of the northern hemisphere and the summer solstice of the southern hemisphere. The consequences are: first, that the winter, or the space of time from equinox to equinox, is about eight days longer in the southern hemisphere than in the northern; secondly, that during the year the southern has about 170 more hours of night than of day, while the northern has about 170 more hours of day than of night; and, thirdly, that the winter of the north pole occurs when the sun is at his least distance from the earth, and that of the south pole when he is at his greatest. From these three reasons it would seem that the amounts of heat at present annually received by the two hemispheres should be unequal, the northern having the most and the southern the least. Now, when we glance at the geography and meteorology of the globe, these two facts are seen: first, that fully three-fourths of the land is in the northern hemisphere clustered about the north pole, while the waters are collected in the southern; and secondly, that the south pole is enveloped and surrounded by ice to a far greater extent than the northern. There is then a considerable degree of probability that some connection exists between these astronomical and terrestrial phenomena, that the former, indeed, may be the cause of the latter. The lower annual temperature of the earth's southern hemisphere during so many centuries may have caused an accumulation of ice and snow whose attraction is sufficient to drag the waters toward it, thus leaving dry the northern lands and drowning the southern with great oceans. Perhaps also the sun's attraction may help to accumulate the waters there. It is hence somewhat probable that there are causes tending to render the earth ovaloidal or egg-like in shape, the large end being at the south and the small at the north.

The process of finding the dimensions

of an ovaloid of revolution to represent the form of the earth would be essentially the same as that already described for the spheroid and ellipsoid. First, the equation of an oval should be stated and, preferably, one that by the vanishing of a certain constant reduces to an ellipse. From this equation an expression for the length of an arc of north and south latitude can be deduced, and this be finally expressed in terms of the small deviations between the plumb lines and the normals to the ovaloidal meridian section at the latitude stations. The solution of these equations by the method of least squares will give the most probable values of the constants, determining the size and shape of the oval due to the data employed. Such computations have not yet been undertaken on account of the lack of sufficient data from geodetic surveys in the southern hemisphere. Since such surveys can only be executed on the continents and largest islands, it is clear that such data will always be few in number compared with those from the northern hemisphere. Pendulum observations, discussed on the hypothesis of a spheroidal globe, by Clairaut's theorem, are able, however, to give some information concerning it, but, unfortunately, the number of these thus far made south of the equator is not sufficiently large to render them of much value in the investigation. It is probable that in years to come pendulum observations, or other methods for measuring the intensity of gravity, will be more employed than they are at present; and since they can be made on small islands as well as on the main lands, it is possible thereby to obtain knowledge concerning the separate ellipticities of the two hemispheres.

An important idea to be noted in this branch of our subject, is that the surface of the waters of the earth is, probably, not fixed but variable. About the year 1250, the perihelion and the northern winter solstice coincided, and the excess in annual heat imparted to the northern hemisphere was near its maximum. Since that date they have been slowly separating and are now nearly eleven degrees apart. This separation increases annually by about 61″.75, so that in the year 11700, or thereabouts, the perihelion will coincide with the southern winter solstice. Then the condition of things will be exactly reversed; the northern hemisphere will receive less heat than the southern, and if to such a degree as we have conjectured above, then the ice will accumulate around the north pole, the waters will flow back from the south to the north, the lands in the northern hemisphere become submerged while those in the southern are left dry. The change will be so slow that during no single century will it be scarcely measurable, yet it may be sufficient to alter the values of the northern quadrants by one or two kilometers. The period of a complete cycle is about 20,900 years, so that in the year 22150, of the Gregorian calendar, conditions will exist similar to those in 1250. Long before that time it is not improbable that civilization will disappear and a cloud of intellectual darkness settle over mankind. Possible enough, too, is it that in that remote age, as in the two centuries following the year 1250, men may waken out of their mental stupor and begin to make feeble inquiries about the size and shape of the earth on which it is their destiny to dwell.

V.—The Earth as a Geoid.

The word Geoid is used to designate the actual figure of the surface of the waters of the earth. The sphere, the spheroid, the ellipsoid, the ovaloid, and many other geometrical figures may be, to a less or greater degree, sufficient practical approximations to the geoidal or earthlike shape, yet no such assumed form can be found to represent it with precision. The geoid, then, is an irregular figure peculiar to our planet; so irregular, indeed, that some have irreverently likened it unto a potato; and yet a figure whose form may be said to be subject to fixed physical laws, if only the fundamental idea implied in the name be first clearly and mathematically defined.

The first definition is, that the surface of the geoid at any point is perpendicular to the direction of the force of gravity, as indicated by the plumb line at that point. From the laws of hydrostatics it is evident that the free surface of all waters in equilibrium must be parallel to that of the geoid; and the second definition determines that our geoidal surface to be investigated is that coinciding with the surface of the great oceans, leaving out of consideration the effects of ebb and flood, currents and climate, wind and weather. Under the continents and islands this surface may be conceived to be produced so that it shall be at every point perpendicular to the plumb-line directions. If a tunnel be driven exactly on this surface from ocean to ocean it is evident that the water flowing from each would attain equilibrium therein, and its level finally show the form of the geoid along that section of the earth.

To obtain a clearer idea of the properties of the geoid, let us consider again the meridian arc measured by the United States Coast Survey in New England, and particularly the following values of the latitudes at the latitude stations:

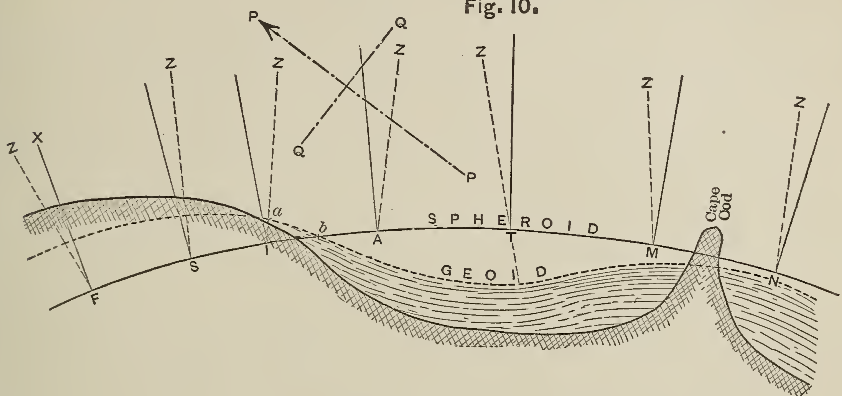
Stations.	Astronomical Latitudes.	Geodetic Latitudes.	Diff.
	° ′ ″	° ′ ″	″
Farmington ..	44 40 12.06	44 40 14.31	+2.25
Sebattis	44 8 37.60	44 8 36.68	−0.92
Independence.	43 45 34.43	43 45 32.47	−1.96
Agamenticus .	43 13 24.98	43 13 23.16	−1.82
Thompson....	42 36 38.28	42 36 40.24	+1.96
Manomet.....	41 55 35.33	41 55 36.77	+1.44
Nantucket....	41 17 32.86	41 17 33.66	+0.80

The column headed astronomical latitudes contains the values observed—that is, the angles included between a line parallel to the earth's equator and the plumb line directions at each point; while the other column contains the geodetic latitudes—that is, the angles included between a line parallel to the earth's equator and the normals to a Bessel spheroid, as computed by the use of the triangulation. The plumb-line directions as given by the geodetic latitudes are hence normal to the spheroid, while those as shown by the observed astronomical latitudes are normal to the geoid. The differences of these two, as noted in the last column, are the same as the angles between the two normals, and indicate the relative plumb-line deflections at the stations. The following figure shows on a small scale the general trend of the coast, the position of the latitude stations and the meridian arc. It might, perhaps, be expected in advance that the actual directions of the plumb lines at these points would deviate northwestwardly from the normals to a spheroid for two reasons: first, because of the heavier continent lying north and west; and secondly, because of the lighter waters lying south and east. To judge concerning this, let us imagine a section of the earth and the spheroid and the geoid along the meridian arc. Let F be a point on this meridian having the same

Fig. 9.

latitude as Farmington, S a point having the same latitude as Sebattis, and similarly for the other stations, and let us consider that the plumb-line directions at these points are the same as at the latitude stations themselves, as far at least as north and south deviations are concerned. Draw, as in the next figure, an arc of an ellipse FSIATMN to represent a section of the spheroid along the meridian arc, and let the distances FS, SI, etc., be laid off to scale equal to the distances as found from the base line and triangulation (and which are given in the last lecture). Draw at these points the normals to the ellipse; these will make with QQ, parallel to the earth's equator, angles equal to the above geodetic latitudes. At F draw a line FZ making with QQ an angle equal to the observed astronomical latitude, so that SFX represents 2″.25, the plumb-line deviation at F. Draw at each of the other points similar broken lines, each of which must indicate the direction of the true zenith Z of its respective station. Now, the surface of the Atlantic ocean coincides with that of the geoid; let there, then, be drawn in the plane of the section a broken curved line perpendicular to the true plumb-line directions to represent this surface and let it be produced under the continent according to the same law. The figure now exhibits roughly the probable approximate relative positions of the spheroid and the geoid along this meridian arc, and a careful study of it will be advantageous in enabling us to clearly perceive some of the principal

Fig. 10.



properties of the geoidal surface. We observe that under the continents it tends to arise higher, while on the seas it tends to sink lower than the surface of a spheroid of equal volume. (But probably never is it convex toward the earth's center as indicated in the exaggerated drawing.) The reason of this is easy to see when we regard the geoid as a figure formed under the action of the attractive force of the matter of the globe. The attraction of the heavier and higher continents lifts, so to speak, the geoidal surface upward, while the lower and lighter ocean basins allows it to sink downward toward the earth's center. But the figure also shows that this rule has its exceptions; the true vertical or plumb-line direction at Farmington, for instance, inclines to the northward of the zenith of the normal to the spheroid instead of southward, as we perhaps might expect it to do. Such anomalies are, in fact, very frequent, and from them we conclude that the earth's crust is of quite variable density, and that this causes the apparent irregularities in the directions of the force of gravity in neighboring localities.

We may now also see that what we have called plumb-line deflections are really something artificial, depending upon the use of a particular spheroid. The geoid is an actual existing thing, the spheroid is not, but is largely an assumption introduced for practical and approximate purposes. At the station F, in the above figure 10, the direction FZ is the only one that can be observed, and the angle made by it with QQ has been measured with a probable error of less than one-tenth of a second of arc. The angle ZFX, or the so-called plumb-line deflection at F, will hence vary with the elements of the particular spheroid employed, and with the correct orientation of geoid and spheroid. A geodetic latitude is something that cannot be directly measured, and therefore it seems that the plumb-line deviations for even a particular spheroid cannot be absolutely found until observations have been made over an extent of country wide enough to enable us to judge of the laws governing the geoid itself. A very slight change in the position of the above elliptical arc may add or substract a constant quantity from each of the angles between the true verticals and the normals. The differences of the plumb-line deflections at neighboring stations will, however, always remain the same. For instance, at T and M the excesses of astronomical over geodetic latitudes are 1″.96 and 1″.44, whose difference is 0″.52; but the spheroid may also be drawn giving 1″.66 and 1″.14 for these deviations and their difference is likewise 0″.52. Strictly speaking, then, it is not the plumb line which deflects, but it is the normal to an artificial spheroid or ellipsoid which deviates from the constant plumb-line direction.

Compared with a spheroid of equal volume, our geoid has a very irregular surface, now rising above that of the spheroid, now falling below it, and ever changing the law of its curvature, so as to conform to the varying intensity and direction of the forces of gravity. Where the earth's crust is of most density and thickness there it rises, where the crust is of least density and thickness there it sinks. From a scientific point of view it will be valuable to know the laws governing its form and size; from a practical point of view it appears that until these are known the earth's figure can never be accurately represented by a sphere or spheroid or ellipsoid, or other geometrical form. For instance, if it be desired to represent the earth by an oblate spheroid, the best and most satisfactory one must be that having an equal volume with the geoid, and whose surface everywhere approaches as nearly as possible to the geoidal surface. This latter condition may be mathematically expressed by saying that the sum of the elevations and depressions between the two surfaces shall be a minimum. Such a spheroid cannot, of course, be found until more and better data concerning the geoid have accumulated, yet what has already been said is sufficient to indicate that the dimensions at present used are probably somewhat too large. Granting that in general the geoid rises above this spheroid under the continents and falls below it on the seas it seems evident, since the area of the oceans is nearly three times that of the lands, that the intersection of the two surfaces will always be some distance seaward from the coast line (as seen at *b* in Fig. 10). Now geodetic surveys can only be executed on the continents, and even if they be reduced to the sea level at the coast (*a* in Fig. 10), the elements of a spheroid deduced from them will be too large to satisfy the above condition of equality of volumes (for the ellipse through *a* is evidently larger than that through *b*). At present it would be almost a guess to state what quantity should be subtracted from the semi-axes of the Clarke spheroid on account of these considerations; but there are reasons for thinking that 1,000 meters would be too much.

We have now to briefly consider the important question, how can the shape and size of our geoid, and its position with reference to the earth's axis of rotation, be determined? From what has already been said, it is not difficult to conclude that a fair mental picture of its surface may be acquired for a locality where precise geodetic surveys have been executed. At points along the coast let the sea level be determined as due to the earth's attraction alone, the effect of tides, currents and storms being eliminated. These are points on the geoidal surface, and it may be imagined to be produced inland, so that everywhere it shall be perpendicular to the direction of the force of gravity. To obtain numerical data regarding its form and position, it may referred to the surface of a spheroid, the direction and amount of the plumb-line deflections indicating always its change of curvature and its relative elevation or depression as compared with the spheroid. But on the oceans, where geodetic operations cannot be executed, it will, probably, ever be impossible to obtain such numerical results. At the present time there is very little known regarding the actual figure of the geoid even on the continents. The word Geoid, in fact, with all the fruitful ideas therein implied, is not yet ten years old, and in all relating to it theory is in advance of practice. Bruns, for instance, has demonstrated that the mathematical figure of the earth may be determined independently of any hypothetical assumption concerning the law of its formation, provided that there have been observed at and between numerous stations five classes of data, namely, astronomical determinations of latitude, longitude and azimuth, base line and triangulation measurements, vertical angles between stations, spirit leveling between stations, and determinations of the intensity of the forces of gravity. These five classes are sufficient for the solution of the problem, but also necessary, that is, if one of them does not exist, a hypothesis must be made concerning the shape of the earth's figure. These complete data have, however, never yet been observed for even an extent of country so small as England, a land probably more thoroughly surveyed than any other. To render geodetic results of the greatest scientific value, it is hence necessary that either the pendulum, or some instrument like Siemens' bathometer, should be employed to determine the relative intensity of the forces of gravity at the principal triangulation stations, and that trigonometric leveling, by vertical angles, should be brought to greater perfection. But years and centuries must roll away before sufficient data shall have accumulated to render a theoretical discussion possible and satisfactory.

In conclusion, it will be well to note that our geoid is not a fixed and constant figure. Upon the earth men build towns and cause ships and trains to glide; simultaneously with these movements of matter wrinkles and waves appear in the geoidal surface. But the changes that man can effect are infinitesimal in comparison with those produced by nature. The atmospheric elements are continually at work to tear down the continents and fill up the ocean basins; ever conforming to such alterations the geoid tends to nearer and nearer uniformity of curvature. Internal fires cause parts of the earth's crust to slowly rise or fall, and immediately the geoidal surface undergoes a like alteration. As the center of gravity of the earth oscillates north and south during the long apsidial cycle of 20,900 years, the position and shape of the geoid will vary slowly with it. Perhaps also the axis of rotation of the earth may not be invariable with respect to its mass but subject to slight oscillations. The changes produced by these causes are not all so minute as to escape detection, for already small but measurable variations have been discovered in the latitudes of several of the oldest observatories, and we may expect that in future centuries other alterations still will be noticed and observed and discussed. When the laws governing these changes shall have become understood, it will be possible to reason more accurately than now concerning the past history and future destiny of our earth.

THE PANAMA CANAL.

By Captain BEDFORD PIM, R. N., M. P.

PART I.

INTRODUCTION.

Again we have the project of interoceanic communication between the Atlantic and Pacific brought before the world; this time in a manner which is calculated to arrest the attention and stimulate the energy of those interested, for has it not been introduced by one whose name is a household word in connection with the great work of his life, the Suez Canal? Need I say that I refer to M. le Comte Ferdinand de Lesseps.

THE PARIS CONGRESS.

The mode adopted to give prominence to the desired enterprise, of opening the American Isthmus, was by calling a Congress at Paris to adopt the best route. Such a Congress was accordingly convened under the auspices of the French Geographical Society and M. de Lesseps, and held its sittings from the 15th till the 28th of May of this year (1879).

At first sight, this would seem to have been an admirable plan to call attention to the project, and insure a practical result, but, unfortunately, Congresses, like Departmental Committees, are neither infallible nor even independent, and the selection of a route for the proposed canal seems to have been a foregone conclusion.

PANAMA SELECTED.

The line chosen was parallel, as near as possible, to that of the Panama railway, and was voted for by a great majority, as the following extract from the report of Admiral Ammen to the United States Government will show:

"At 1.30 [on the 28th of May, 1879] the final full meeting of the Congress took place, the report, *résumé*, and resolution were read, and the yeas and nays taken upon the latter, resulting in a vote or abstention of 99 members out of 135, as given in the list—seventy-five voting yes, eight no, and sixteen abstaining. The character of the voters and of those who absented themselves will appear in the report of Civil Engineer Menocal. I abstained from voting on the ground that only able engineers can form an opinion after careful study of what is actually possible, and what is relatively economical, in the construction of a ship canal.

"The text of the resolution is as follows:

"'Le Congrès estime que le percement d'un canal interoceanique à niveau constant, si désirable dans l'interêt du commerce et de la navigation, est possible, et que le canal maritime, pour répondre aux facilités indispensables, d'acces et d'utilization que doit offrir avant tout un passage de ce genre, devra être dirigé du Golfe de Limon à la baie de Panama.'

"The hall was densely crowded, many ladies being present; about one hundred members or delegates, and three to four hundred other persons. Whenever a vote of 'yes' was given, especially by some one who had more or less opposed the conclusion, a very enthusiastic clapping of hands occurred, which would hardly have been the case had the audience regarded the selection as depending wholly on natural conditions or advantages, or on physical causes. The Congress then adjourned."

M. DE LESSEPS.

It is impossible to disguise from oneself that the strong and very natural personal feeling of the members of the Congress towards M. de Lesseps was allowed to override a strict practical dealing with the subject, which alone could command the respect and adhesion of the public.

Strangely enough those most deeply concerned seem either to have taken but little interest in the proceedings, or to have been left out in the calculation vulgarly called "counting noses." Be that as it may, the practical result of the Congress amounts to this, that a "Panama Canal" was voted, and its execution entrusted to M. de Lesseps. The United States, through their official delegate, Admiral Ammen, did not approve of such a decision, preferring, for very substantial reasons, the route by way of the River San Juan and the lakes of Nicaragua.

AMERICAN, ENGLISH, AND FRENCH INTERESTS.

In discussing the subject of interoceanic communication between the Atlantic and the Pacific Oceans, it is very necessary to ask ourselves the question, "Who are those interested?"

Now, I have given this matter very serious consideration, and I have come to the conclusion that, while it is true that every nation under the sun may claim to have an interest in the international work of piercing the isthmus of the New World, if only from a sentimental point of view, yet, practically, the success of the undertaking depends upon three parties.

Of these parties, first and foremost stand, of course, the American States. I do not mean the United States, but all the States of America. Secondly, England; and thirdly France, though in a minor degree, and simply because she has possessions in the West Indies, and has long been desirous of extending her commerce across the isthmus into the Pacific.

These three nations, then, are "those interested," upon whom will devolve the risk and expense of an undertaking, which it cannot be denied, must be one of very considerable proportions.

HOW REPRESENTED AT CONGRESS.

Let us see how these interests were represented at the Paris Congress; and, first, as regards France, I think it may fairly be said that it would have been impossible to find a better representative than M. de Lesseps. I will even go a step further, and say that it would have been more satisfactory if M. de Lesseps, in the first instance, had embodied the Congress in his own proper person, and exercised his great practical intelligence without seeking the uncertain and heterogeneous assistance of a Congress at all. England was not officially represented, although it is quite true that Colonel Stokes was announced as our delegate. Upon writing, however, to the Foreign-office on the subject, I received the following reply, which settles the matter, and correctly measures the interests taken by our Government:

LETTER FROM FOREIGN OFFICE TO CAPTAIN PIM.

"Foreign office, May 8th, 1879.

"SIR:—Lord Salisbury has desired me to acknowledge the receipt of your letter of the 3rd inst., inquiring whether it is true that three delegates have been appointed by her Majesty's Government to attend the Conference at Paris on Interoceanic Transit across Central America.

"In reply, I am to inform you that no delegate has been officially named to represent this country, but that Sir John Stokes has been invited by M. de Lesseps to attend the Conference, and he has received the permission of the Government to accept the invitation.

"I am, sir, your obedient servant,
(Signed) PHILIP CURRIE.

"Captain Bedford Pim, M.P."

In respect to the United States, not only was a representative appointed in the person of a distinguished officer of the Navy, Rear-Admiral Daniel Ammen, assisted by Anecito G. Menocal, Esq., Civil Engineer of the United States Navy, but particular instructions were given to the Admiral for his guidance in the important mission with which his Government had entrusted him.

The following is a copy of the instructions given to Admiral Ammen; they are of value in this connection as showing the very natural interests taken by the Government of the United States in any project for piercing the isthmus of their country:

ADMIRAL AMMEN'S INSTRUCTIONS.

MR. EVARTS TO ADMIRAL AMMEN.

"Department of State,
"Washington, April 19th, 1879.

"Rear-Admiral Daniel Ammen, U.S.N.,
"Washington, D.C.

"SIR:—The President having appointed you to be a Commissioner on behalf of the United States, to attend an International Conference to assemble at Paris, on the 5th of May proximo, under the auspices of the Geographical Society of Paris, for the purpose of considering the various prospects of an international canal across the American Isthmus, I have the honor to acquaint you officially with the fact of such appointment. It is also incumbent upon me to give you certain instructions for your guidance, in the execution of the President's wishes. The importance and magnitude of the projected enterprise are such as to command earnest attention, especially on the part of those countries whose trade is to be affected in a marked degree by the success or failure of the scheme.

"This Government, in the interest of its rapidly growing commerce, not only between its own Atlantic and Pacific shores, but with the other American States on the western coast of the Continent deems it advisable to keep itself well informed on the subjects, and also to give any useful information in relation thereto to other governments interested in the scheme of inter-oceanic communication.

"You are accordingly instructed to attend the Conference of the International Commission concerning the opening of an interoceanic canal through the American Isthmus, to be held at Paris next month, and you will be expected to carefully watch its progress and results, and report them to your Government.

"You will take part in the discussions of the Conference, and will communicate such scientific, geographical, mathematical, or other information as you may possess, and as is desired or deemed important. In this work you will be assisted by Civil Engineer Anecito G. Menocal of the United States Navy, who has been detailed and appointed a Commissioner for the purpose with like powers. You will, however, have no official powers o diplomatic functions.

"You will hold no official communication with the officers of the French Government, except such as may, by virtue of their connection with the French Geographical Society, or as delegates, *ad hoc*, take part in the proceedings of the Conference. You are not authorized to state what will be the decision of the Government of the United States in regard to the points involved or the line of action it will pursue.

"The Conference is understood to be, not one of diplomatic representations of the respective governments, but rather a gathering of scientific men and public officers, whose experiences render it desirable that they should have an opportunity for the exchange of information and of views. Your well-known wide acquaintance with the subject proposed to be discussed makes it peculiarly fitting that you should be selected to meet other distinguished engineers and officers who have given like attention to the matter.

"You are furnished herewith with such documents and records as the files of this and other departments contain, that may be of interest and importance.

"Your own familiarity with the subject, and careful study of it in all its bearings, render it unnecessary to give you further instructions on this point.

"I am, sir,

"Your obedient servant,

"William M. Evarts."

These instructions sufficiently attest the interest attached by the United States to the canalization of the American Isthmus, which is also manifest by the light of subsequent events; still no attempt whatever has been made to embarrass in the slightest degree the movements of M. de Lesseps, although means have been taken to make it known that the route which will be favored by the United States is not that selected at the Paris Congress; on the contrary, the scheme of M. de Lesseps will be avoided altogether, and the canal built, if anywhere, through Nicaragua, although the exact direction will not be decided upon without further surveys and lines of new levels.

Upon this point, and to show the steps already taken by our energetic cousins across the Atlantic, I beg to call your attention to an extract from the *Times* of the 4th October last.

The following is General Grant's letter to Admiral Ammen, in which he consents to the latter's request to take the presidency of the proposed Nicaragua Canal Company:

"Tokio, Japan, August 19.

"*My Dear Admiral:* Your letter of the 2d of July reached me a few days since. After two days reflection of the part I should take or consent to take—if offered—in the matter of the interoceanic canal, *via* Nicaragua, I telegraphed to the Secretary of the Navy at Washington: 'Tell Ammen I approve.—Grant.' I hope you received the despatch. On the 27th, two weeks after this leaves Yokohama, we sail for San Francisco. I do not feel half so anxious to get home as I did eighteen months ago. There is no country which I have visited, however, this side of Europe, except Japan, where I would care to stay longer than to see the points of greatest interest. But Japan is a most interesting country, and the people are quite as much so. The changes that have taken place here are more like a dream than a reality. They have a public school system extending over the whole empire and affording facilities for a common school education to every child, male and female. They have a military and a naval academy which compare well with ours in the course taught, the discipline, and the attainments of the students. They have colleges at several places in the empire on the same basis of instruction as our best institutions. They have a school of science which I do not believe can be surpassed in any country. Already the great majority of their professors—even those engaged in teaching European languages—are natives, most of them educated in the very institutions where they are now teaching.

"But I hope to meet you soon, and then I will say more on this subject than I care to write in the limit of a letter.

"Mrs. Grant sends her love to Mrs. Ammen and the children. Please remember me kindly also.

"Yours truly, U. S. Grant.

"Admiral D. Ammen."

RESUME.

This, then, is the position of affairs. Through the influence of M. de Lesseps, a Congress was convened, and met at Paris in May last. It consisted of 135 members, and the result of its action was a vote of confidence in M. de Lesseps, and his favorite plan, as embodied in the following resolution, was carried by ayes, 75; noes, 8; not voting, 16; absent, 36.

"The Congress considers that the cutting of an interoceanic canal at the sea level, so desirable in the interests of commerce and navigation, is possible, and that a maritime canal, to afford those indispensable facilities of access and utility which such a passage must, above all things, possess, should be carried from the Gulf of Limon to the Bay of Panama."

A canal, *à niveau constant*, at the sea level, and without locks, is no doubt the most desirable mode of joining together two oceans. No process can be more simple, if only the intervening land is level and below the level, as at Suez (M. de Lesseps' model work), and there is besides every advantage in the shape of climate, abundance of labor, and the ease with which labor-saving appliances can be used; but it is a very different affair when the reverse is the case, and, moreover, the harbor accommodation at either end is, to use a mild term, indifferent. From these causes alone the work of opening a canal between the Atlantic and Pacific across the Isthmus of Darien or Panama assumes gigantic proportions, and bears about the same proportion to that at Suez as the excavation of Mount Cenis to the boring of a tunnel under the Thames to-day. It is not, therefore, to be wondered at that adverse criticisms were leveled at M. de Lesseps' scheme, even before the breath was out of the body of the Congress; and, that the subsequent growth of such criticisms has had the effect of staying his proceedings, so that at present the scheme of cutting a canal, *a niveau constant*, on a line parallel to that of the Panama railway, is in abeyance.

Indeed, the project is not likely to be revived, for independently of the difficulties I have mentioned, the locality is not adapted for the purpose in view, owing to the persistent calms which effectually bar the approaches to sailing ships, and vex the navigation beyond endurance.

I have had long experience of the physical geography of Central America, and the Bay of Panama in particular. On one occasion, the frigate *Herald*, in which I was serving, was towed by H. M. S. *Sampson* 700 miles off the land before picking up the slightest breeze; but although my practical experience on both sides of the isthmus happens to be very extensive, I will not on this occasion rely upon it, but call your attention to a letter bearing on the subject, addressed to me from my old friend, the late Commodore M. F. Maury, LL.D., familiarly known to us—I may truly say to all the world—as the author of that charming work, "The Physical Geography of the Sea." His name is a household word as the greatest authority on this subject, not only among his own countrymen in the United States, but quite as much with us Englishmen. His letter is dated as far back as July, 1866, and I am sure the members of the Society of Arts will have much pleasure in seeing it published in full in their *Journal*, as a most important contribution to our scientific knowledge of the Isthmus of the New World.

Commodore Maury tells us in the plainest language that "If nature, by one of her convulsions, should rend the Continent of America in twain, and make a channel across the Isthmus of Panama or Darien, as deep and as wide and as free as the Straits of Dover, it would never become a commercial thoroughfare for sailing vessels." I have only to endorse this opinion, for, of all parts of the world I have ever visited, the calms which prevail in the Bay of Panama are the most vexatious and enduring.

It is, therefore, by no means surprising that M. de Lesseps is taking time to reconsider his position, and, from what I know of that gentleman's character, I hope and believe that such consideration will be so shaped that his genius, his experience, and his wonderful energy and perseverance will, under no circumstances, be lost to those who seek the junction of the Atlantic and Pacific, no matter by what route, or whether at the sea level, or with or without locks.

The following is the late Commodore Maury's letter on the physical geography of Panama and Nicaragua:

My Dear Captain Pim: I had occasion some years ago to study, more or less closely, almost every route between the British possessions on the north and the Isthmus of Darien on the south, whether for rail or canal, that had up to that time been attempted or projected across the American continent.

Owing to the character of the researches with which I have been for more than twenty years engaged, my attention was directed to those routes rather in their physical and commercial aspects, than to their topographical features, or to their facilities of construction.

The great importance of one or more good commercial highways across Central America being admitted, the whole question as to route resolves itself pretty much into a question of the cost of construction, and the facilities of ingress and egress by sea, to and from the opposite termini; the latter is an affair of winds and currents. Their influence is powerful. Panama has the advantage in shortness of land transit; Nicaragua has the advantage in winds, terminal ports and climate. The first is obvious: but to place the latter in a clear light, a little explanation may be necessary.

To make this explanation clear, let us, with Panama as a center, take a general survey of the winds as they prevail in the Pacific ocean.

As a rule, the prevailing winds in all that belt of ocean extending from the parallel of 35° north down to the parallel of 35° south, are from the eastward. This belt is 70° of latitude broad; in it are included the bands of the northeast and south-east trade winds, and the belt of equatorial calms; the latter separates the two systems of trades, and extends all the way across the Pacific.

Looking westward, therefore, from Panama towards the islands of the Pacific, or towards Australia, China or Japan, you observe that Panama is directly to windward of them all—and that, therefore, whilst the commercial routes from Panama to any of these places are all down hill, or to leeward, the way back is up hill, to windward (for over this broad band of the ocean easterly winds blow all the year, except now and then, when they are interrupted for a short time by the monsoons). Still, by making a detour, the return voyage to Panama would not be so difficult as from this statement it would appear to be, were it not for other physical conditions which stand in the way of navigation.

I have spoken of a calm belt about the equator; Panama is within its range. Owing to the contour of the central American isthmus, the height and direction of the mountain ranges by which it is traversed, and the influence of these upon winds, this calm belt is greatly enlarged on the Pacific or lee side of the Isthmus.

It is difficult to convey to one who has never experienced these calms, an idea of the obstinacy with which they vex navigation. We are all familiar with calms at sea, which last for a few hours, or even a day, but here they last for days and weeks at a time. I have known vessels going to or from Panama to be detained by them for months at a time. An American sloop-of-war, bound from Mazatlan, in Mexico, to Callao, in Peru, once attempted to make a short cut by running down the coast. She finally succeeded in passing these Panama calms, but she was delayed and baffled by them and the adverse currents from the south, until her provisions fell short, and she had to put into Payta to avoid starvation. The Humbolt current, which skirts the coast of South America all the way from Cape Horn, is felt in the offings of Panama.

The Gallapagos Islands, a fine and fertile group, are within the influence both of this current and of these calms; they are about 600 miles from Panama and about 500 from the South American coast; they tell, in their mute way, a curious story about these calms. Though so near the Continent of America, they are the only islands in that wide ocean capable of sustaining a population, that were uninhabited when discovered. The reason is to be found in these calms; and simply because the wind there never blows continuously enough to waft a canoe from any quarter upon their shores.

On one occasion the British admiralty, wishing to send one of their sailing vessels into the Arctic Ocean from Panama in time to save the season, had her towed by a steamer through the calm belt, and carried 700 miles out to sea before she could find a breeze.*

Panama is not in the center of this calm belt; it is to the north of the center, and consequently a sailing vessel, by shaping her course directly south from Panama, would, though bound for Peru or Chili, not only have to encounter the force of the Humboldt current, feeble though it be, but she would get into the thick of these

* H. M. S. *Herald*, in which ship Captain Pim was then serving.

"doldrums;" she must, therefore, to avoid them, be content to run along to the westward for upwards of 200 miles until she approaches the coast of Costa Rica. Here the coast-line trends off to the northward and westward; she follows it, reaching the latitude of Realejo before she can get fairly within the north-east trade winds, upon which she depends for gaining an offing and getting fairly out to sea. Having come up to them, she stands off to the southward and westward with flowing sheets, taking care not to cross the belt of equatorial calms within a thousand miles of Panama, nor until she can reach it in a much narrower part. Her port now lies to the southward and eastward, but she has entered the south-east trades, which are directly ahead. Consequently, she has to stand off on a bow line to the southward and westward, until she can clear these winds and get others from the west; this takes her as far south as 35°, and often beyond 40°. Here she makes her easting, taking care to bring her port so to bear, that she can fetch it with the south-east trades again. Such is the way often taken, under canvas, from Panama to Valparaiso, the "Chinchas," Calleo, and all the "Intermedios." This is a curious route, but one that is not unfrequently pursued by the cleverest navigators; it would be well, for the better understanding of these facts, to refer to the map, for in consequence of these calms (and there are no others in the world like them) you will observe that this route actually takes the ship farther beyond, or to the south of "the Chinchas," if they be her destination,—than she was to the north of them when she got under way from Panama.

Upon the rush which took place for California, in consequence of the discovery of gold there, the route at first pursued by the sailing vessels, which doubled Cape Horn, both from Europe and America, was to cross the equator in the Pacific, in about longitude 90° west. This brought them along the outer edge of the Panama region of baffling winds, and made their average voyage out, one of six months. Cases occurred on this route, in which the passengers, to avoid starvation, actually abandoned their vessel in these calms, took to their boats, and so reached land.

This continued to be the route until the investigations of the winds and currents in the Pacific (to the results of which investigations I am still speaking) enabled me to point out a better one. Captains were then advised to avoid those Panama calms, and instead of crossing the equator in the Pacific, near the meridian of 90° west, they were recommended to cross it some 25° or 33° more to the westward. They did so, and this is the favorite route under canvas now; and the passage by it, instead of requiring six months, averages four.

These remarks apply to the approach and departure by sea to or from the Pacific terminus of any route across the Isthmus of Panama or Darien, and even with greater force to the Atrato and others on the South American side of Panama. In short, the results of my investigations into the winds and currents of the sea, and their influence upon the routes of commerce, authorize the opinion which I have expressed before, and which I here repeat, namely—if nature, by one of her convulsions, should rend the Continent of America in twain, and make a channel across the Panama or Darien as deep, and as wide, and as free, as the Straits of Dover, it would never become a commercial thoroughfare for sailing vessels, saving the outward bound and those that could reach it with leading winds. Steamers would, and coasters might, use it, but homeward bound vessels in the China, India, or Australian trade, rarely.

Such, so far as the winds are concerned, are the physical difficulties in the way of a great commercial highway at the southern extremity of Central America, and which no engineering skill, however great, can overcome. I shall have occasion to refer again to the Panama route for other contrasts.

In the meanwhile, let us turn to the most northern of these Central American routes, for which subventions have been obtained.

After, and in consequence of, the discovery of gold in California, the subject of a shorter and better route than that in use—viz., the "180 day's passage," *via* Cape Horn, was discussed in commercial circles. A "gateway" to the Pacific now for the first time engaged the earnest attention both of the people and Government of the United States. The route next in favor after that of Panama, especially in New Orleans, was that called the Tehuantepec route, having its Pacific terminus in the Gulf of that name, and its Atlantic terminus at the mouth of the Coatzacoalcos river. It had attracted the attention of Cortez—the world was familiar with the idea of a grand commercial throroughfare there. A grant with munificient franchises had already been obtained from Mexico, and a company was speedily organized with ample means, first to construct a plank-road between the head of the navigable streams on the two sides, and then a ship canal.

This route was much more attractive than the Panama Route to the people inhabiting the Mississippi Valley; Panama is nearly equi-distant from New York and New Orleans, but the Tehuantepec route would be a saving to the States bordering on the Gulf of Mexico, of no small moment both in time and distance, for its eastern terminus is almost at their door. With a strong bias in its favor, I was invited to discuss its merits. I was forced nevertheless to condemn it, and to decide, as between the two, in favor of Panama, at that time its rival in the money market and for the public patronage.

The Tehuantepec route was condemned as impracticable for two principal reasons: no engineer could be found rash enough to undertake, for any practicable sum, to build a safe harbor for its terminus on the Pacific, and deepen the water on the bar at the mouth of the Coatzacoalcos. Moreover, the violence of the "northers," for which the Gulf of Mexico is celebrated, would make the anchorage off its eastern terminus for ever unsafe at certain seasons. This route, therefore, was abandoned, although the climate, the resources on the wayside, and the distance, were all greatly in its favor. It lacked harbors.

No other route to the north of the peninsula of Yucatan has been brought to my attention.

Passing it, we leave the Gulf, and enter the waters of the Caribbean Sea, from which various routes have been projected, and several of which have been pressed with more or less zeal upon the public; none of these, however, save the several Nicaraguan routes, seem to have had merits enough to arrest the attention of capitalists, or to deserve serious consideration, except perhaps the Honduras route. Little or nothing is known about the topographical features of that route; I rather fancy a careful survey there would disclose heavy gradients and sharp curves. But, be that as it may, that route, as drawn by the pen on the chart, looks very attractive, both on account of its shortness and the harbor facilities afforded for each terminus. Its terminus on the Pacific is close to that selected for the Nicaraguan road, and is quite as commodious. But admitting the gradients to be ever so easy, and the curves few and gentle, the winds interpose an obstacle that is fatal to this route as the highway of commerce between the two oceans.

Look at the chart; you observe that the eastern terminus of this route is in the corner of the coast, forming a right angle and opening out to the north-east. The north-east trade-winds blow home here, and consequently a vessel wishing to clear from this end of the route, no matter for what port, would find herself embayed at the very outset, and under the necessity of a "dead-beat" of 400 or 500 miles, against the whole force of a head sea and the north-east trades, before she could be said to have gained an offing. This would make the passage from this end of the Honduras route to England, but little, if any, short of the homeward passage round the Cape of Good Hope, from India and China, or around Cape Horn from Australia. With this fact staring you in the face, nothing more need be said of the Honduras route until canvas is driven from the ocean by some cheaper and faster means of propulsion.

We come now to the Nicaraguan routes. Of these there are several. Though longer across from ocean to ocean than Panama, some of them have already, and with a degree of success by no means discouraging, competed with it before the world for public favor.

The Emperor of the French himself proposed and advocated the establishment of a great commercial highway across this part of the Continent. Later, M. Belly, adopting his idea, obtained a grant, and proposed to construct a

Nicaraguan ship canal across from sea to lake and from lake to ocean.

At first this project found favor with the Emperor. He was disposed to take it under Imperial patronage. But he was not content with a topographical survey of the route. There were other physical conditions and circumstances which that sagacious monarch knew might exercise a controlling influence over such a work. He, therefore, chose to refer it for examination by the lights which the investigations concerning the winds and currents of the sea might cast upon it, and I was also invited to give my opinion upon it, according to any other information I chanced to possess. For this purpose, M. Belly's data and arguments were all placed before me; but suffice it to say, that when the matter came to be treated in connection with the existing requirements of commerce, this canal scheme proved to be wholly impracticable at the present day, and it was consequently given up.

Another Nicaraguan transit route was started by Vanderbilt and others, of New York, in opposition to the Panama road. They "established a line across," and "put on a line of steamers" to run in connection with it between New York and California. The passengers were conveyed across partly by lake and river steamboats, partly by stage-coaches, and on mules; and yet, although they occupied two days in the transit, this route, even with such drawbacks as these, fairly divided with Panama the passenger traffic. It was finally bought off by the Panama company.

In 1849, this transit company, under the title of "The American Atlantic and Pacific Ship Canal Company," obtained a grant from Nicaragua, and entered into a contract with that State, for the construction of such a work. Eight years after, however, I find them soliciting a modification of this contract, on the ground that there was not water enough in the lakes of Nicaragua to float such ships as the canal was intended to pass. Thus the ship canal question appears to have been disposed of for the second time, and perhaps until the Pacific slopes of Mexico, California, Oregon, and Columbia shall be further subdued, and be more abundantly replenished with inhabitants.

It is through this country and near the canal route that the railroad proposed by you is to run. I have never been on the Isthmus, and know nothing of the engineering difficulties of the road, nor of the typographical features of the country, but have reason to believe that they are by no means difficult. Skillful engineers, both French and American, have examined them. Those of both nations report gradients enough for a canal. We may safely infer, therefore, that the route for your road presents no difficulties that the railway engineer need fear. Indeed, I am assured that the curves are gentle and the gradients easy. In truth, the lakes, their distance from the sea and their height above it, indicate that the summit-level is to be attained without any very steep ascents.

It is to this part of the Isthmus too, to which we must look for a route which shall best fulfill the present requirements of commerce between the two oceans, as well as of transportation and travel between the Pacific shores of North America, on the one hand, and the Atlantic shores, both of Europe and America, on the other. The ship canals have all been virtually abandoned, at least for the present, by their original projectors, and the road now proposed is required to supplement the Panama route. The south American markets are now giving the Panama route as much as it can do. English merchants have, within the last few years, put on a line of steam propellers between Panama and the coast south as far as Chili. These have given the road an enormous incaease of traffic; no such increase has come from the North American side. Your road would draw it from that quarter, and vessels under canvas would, in the main, do the fetching and carrying for the Nicaragua route, which, for reasons already stated, cannot be done for Panama. The aggregate amount of this trade is immense, and it is neither accommodated for Panama, nor Panama for it. For this reason, as I have said, one route will supplement the other. One has already its chief traffic with the south coast, the other will have it with the north, the islands of the Pacific, and its western shores.

Nicaragua will also receive by canvas,

from the ports of Chili and the South, an immense amount of commerce that cannot afford to go to Panama by steam, and that never will reach it by canvas.

Moreover, though the distance, as the crow flies, from Nicaragua to Chili and Peru, is greater from Nicaragua than it is from Panama, yet the average sailing voyage is much less in time.

Your road, therefore, as a thorough fare for trade and travel with certain marts in the Pacific, may, in particular aspects, boast of important physical advantages which are wanting to Panama. Do they constitute inducements sufficient to tempt capitalists to embark in it as an investment?

This, I take it, is the real point to which you wish me to come.

The value of the franchises conceded under the grants to each route are better understood by you than by me, for I have not carefully studied either of them; and as for the relative character of the difficulties or facilities which stand in the way of the engineer or beckon him on, you require no opinion from me, even if I felt myself qualified to express one, which I do not.

Therefore, returning again to the physical features of the Panama route, as I promised to do, we can now compare more in detail than I have yet done the advantages possessed by each, as far as those advantages are influenced by facilities of navigation, by the elements, by salubrity of climate, and by the dictates of commerce.

The French and English Admiralty charts give the most accurate information that I possess concerning the harbors at the opposite ends of the two routes, Panama and Nicaragua—I mean, as to mere anchoring ground, depth of water, and shelter afforded.

It is proper to remark here that I was a great friend, an earnest advocate, and active supporter of the Panama road, giving it in 1849 the preference over all other isthmian routes. At that time my "wind and current" investigations had not extended into the Pacific Ocean; and the discovery of those causes which make the approach and departure to and from the Bay of Panama so very difficult for sailing vessels, had not been sufficiently established to give them their proper weight.

That I may make myself clear as to the obstacles which these researches, confirmed by the experience of the Panama Company themselves, have shown to be in the wap of the Panama route, I send you a chart, on which I have roughly sketched the trade-wind regions of the Pacific, the parts of the ocean where the Panama calms dominate—the deeper the shading the more vexatious the calms—and the route of vessels, trading under canvas, between Panama and the various ports in the Pacific. You will observe at a glance that the Isthmus of Panama, or Darien, is, on account of these winds and calms, in a purely commercial point of view, the "most out-of-the-way" place of any part of the Pacific coast of inter-tropical America.

You will observe also that the offings of Realejo are not beset with calms at all comparable for obstinacy to those which hinder navigation in the bay and offings of Panama. The reason of this is, that Realejo, instead of lying within the range of the Darien calms, lies in the regions of the "little monsoons" of Central America (N. E. trades), which, in August and September, blow from the southwest along this part of the coast. They are "soldiers'" winds for coasters in either direction, and do not extend far to seaward.

In consequence of this difference in the character of the offings of the two routes, the Pacific terminus of the Nicaraguan transit is on the wayside of the sailing voyage from Panama even to Callao and Valparaiso. You observe that the region liable to these Darien calms, extends from a little to the westward of Panama Bay, and thence along the Pacific coast, all the way to the equator It does not cross the continent, but, like a wedge with the blunt edge resting on the land, it extends far away to the west, getting narrower and narrower as it goes, and consequently more easy to cross from north to south, but more difficult to traverse from point to base or from west to east.

With this explanation, it is easy to understand how it is that sailing vessels from Panama often have to go north to get south. That also is the best way to get out to sea when bound in any other direction. Panama is in 90° N.; the distance thence to the equator is between five and six hundred miles. Navigators look on "this passage to the Line as the most perplexing experienced in the Pacific for sailing vessels; thirty days is not considered out of the way, owing to calms, squalls, and torrents of rain which fall during these months,"* *i. e.*, in the rainy season.

H. B. M. ship *Monarch* had to be towed across the line by a screw steamer after leaving Panama and taking this route.†

"Lieutenant Maury," remarks Mr. Hull, Master of H. M. S. *Havanah*, truly says "that the passage under canvas from Panama to California is one of the most tedious, uncertain and vexatious that is known to navigators."‡

Realejo is on the northern verge of these calms, and where they have nearly ceased to be vexatious to the navigator at any season. Here then is the physical advantage in favor of the Nicaraguan route, for which it is difficult to find the money value.

Having obtained an offing from the Pacific terminus of either the Panama or Nicaraguan route, the winds are fair for all voyages, except those on the ports of South America.

But on the return voyage, the Nicaraguan Transit Terminus is again on the wayside from the islands of the Pacific, from California, British Columbia, the mouth of the Amoor, Japan, China, etc. The returning ship has to fetch a compass to the north; this brings her into the westerly winds, which prevail north of the fortieth parallel of north latitude, and lead her along the northwest coast of America. Consequently, in running it down, all such trades have to pass the shores of Nicaragua to get to Panama.

Then in coming from Australia there is a choice of routes: the sailing vessel may either run down to the south of 45° south latitude to make her easting in the westerly winds of that hemisphere, and then steer north; or she may steer north on leaving Australia, cross both systems of trades, and make her easting on the polar side of 40° north. This last route is the one recommended by the sailing directions.

* "Maury's Sailing Directions," 8th edition, 1859, p. 777.

† Ibid.

‡ Ibid., p. 773.

As regards the line of steamers in contemplation between Panama and Australia, they can go straight enough, and have the wind quartering all the way; but returning by the same route they will have a stiff and strong breeze "right in their teeth;" and as the southeast trades are stronger than the northeast, it is probable that even the steamers, upon trial, will find it more convenient to go north about and pass the offings of Realejo on their return voyage to Panama.

But the great centers of trade to which a good commercial highway across Central America would lead and develop, lie principally in the northern and not in the southern hemisphere; and here the Nicaraguan road has greatly the advantage over Panama, by shortening the actual distance.

By the great circle, and consequently the best route for steamers between Realejo, China, Japan, etc,, British Columbia is on the wayside, and by touching at Vancouver—as it is about half way—the voyage between Realejo and Japan or China would be divided into two parts, each about equal to a voyage by steamer between Liverpool and Norfolk in Virginia.

Both of the Isthmus routes have their rainy season: that of Panama is long and trying. In Nicaragua the season is not so long, and there the rains generally come on in the afternoon, after which it clears up till the next afternoon. On the Isthmus of Panama the atmosphere is reeking with moisture, and the rain pours all the time. That calm place is one of nature's condensers. The air there is, during the rainy season, as damp as vapor can make it.

There are certain classes of goods liable to damage in such a damp and warm climate, even during the mere transit, and a larger class that stowage there would ruin. These objections apply also to Nicaragua, but not by any means with equal force, or to such an extent, for this simple reason—its rainy season is not so long or so severe, its climate is not so damp, and its dew-point by no means as high. Many classes of goods, if shipped under canvas from Panama in the rainy season, would be damaged ere the vessel could clear the calm; not so from Nicaragua.

Of all the climates of America, the climate through which the Panama road runs is the most pestilential. Few places in the world are so sickly as to give their names to disease. We hear of the Asiatic cholera and the coast fever of Africa; but the termini of the Panama road are the only places in America that have won this unenviable distinction. The Chagres fever on one side, and the Panama on the other, are known throughout the coasts of that continent, and dreaded by all who visit there.

The "Transit route of Nicaragua" is exempt from these heavy drawbacks of dampness and disease. It passes through a salubrious climate. The soil is productive, its pastures abound in cattle. I never heard of any disease peculiar to the country, nor of especial virulence there.

Both its soil and climate are adapted to the cultivation of coffee, sugar, rice, tobacco, cocoa, indigo, and the like, while in its forests you may gather drugs and spices, with ornamental and dye woods of rare beauty and excellence. These, this route will in the process of time bring into the channels of commerce, and convert into valuable sources of revenue. The Panama railroad has developed no feeders, and its wayside business, in a commercial light, is simply *nil.* It would be very different in Nicaragua.

The Pacific termini of the two routes thus present marked contrast; but with the exception of the "northers," those in the Carribbean Sea offer none worth considering as regards the winds and currents. The harbor accommodations of the Nicaraguan transit appear to be superior to those of Aspinwall; moreover, the former is completely sheltered from the violent winds of that coast, while Aspinwall is open to all their fury, although even the harbor of Aspinwall appears to have answered its purpose.

To conclude, you see the sum of all these disadvantages of the Panama route, expressed by the road itself. It has been opened about twelve years; but sailing vessels go and come by the old routes, as though it were not, and they double Cape Horn in greater numbers than ever. Few are the cargoes of merchandise to or from the east, that have found their way across that road. And though its earnings are enormous, it has, as a commercial highway, disappointed the world and the expectations of its advocates from the time of Columbus down; he thought the "gates of ocean" were there, and his day dreams, as he lay ill with the fevers for which Chagres and Panama have won notoriety, were to "unbar" them. It has not altered a single old route of commerce, but it makes enormous dividends for all that.

That a single track of railway should be enough to do the business between the two great oceans, indicates, in language more telling than I can utter, that there must be, in its way as a commercial thoroughfare, practical drawbacks and difficulties of some sort which the world has overlooked. These I have endeavored to point out.

As a mere pecuniary investment, the Panama railway has, in spite of its drawbacks, turned out to be a profitable one. But it derives its profits, not from the lap of commerce, as its friends supposed it would, but chiefly from the transportation of passengers, mails, and express parcels. Open the "Transit Route of Nicaragua," and that will give a new vent to commerce, besides attracting trade that Panama can never win; it and the Panama route will act and re-act favorably upon each other.

For reasons of State, her Majesty's Government should encourage this work. Nationally, it is of great importance. But upon this aspect of the case it would be out of place for me to dwell.

Respectfully, etc., etc.,

M. F. Maury.

30 Harley street, Cavendish square, July, 1866.

The Great Northern Railway (British) Company has adopted a system of lighting railway carriages for long distances by gas, compressed in vessels containing naphthaline. The system employed has been developed by Mr. Sugg, of Westminster, and practical experiments are now being made with it. The advantages of this system, if any, over the Pintsch's oil gas system—employed on about 500 carriages on the Continent, on our own Metropolitan, and in 250 carriages of the Great Eastern Railway, with supply for thirty-five hours' run—is not stated.

TECHNICAL EDUCATION IN ENGLAND, FRANCE AND GERMANY.

From "The Journal of Science."

The City of London Guilds and other corporate bodies seem at length to be convinced of the absolute necessity of adopting some measures for the advancement of technical education in England. As far back as the Paris International Exhibition of 1867 our English masters and workmen awoke to the fact that the leading position which we had formerly occupied as makers of the world's goods was being endangered by the talent and enterprise of foreign nations. The first note of alarm was sounded by Dr. Lyon Playfair, in a letter addressed to Lord Taunton, the chairman of the School Inquiry Commission then sitting. The aim of this communication was to inquire whether England was really losing her high position in those industries which involve the application of scientific knowledge to production; and, if so, whether this retrogression was due to our comparative backwardness in the diffusion of a knowledge of applied science amongst the working classes. The British Commissioners appreciated the warning at its proper value, and, taking advantage of the presence in Paris of some of the most eminent British men of science of the day, they consulted them on the subject, the result being that, with scarcely a single dissentient voice, they affirmed that the lack of technical education on the part of British masters and workmen was slowly, but surely, undermining the position of Great Britain as mistress of the industrial arts.

Speaking generally these salutary warnings have been neglected, although in some few isolated instances they have been duly acted upon. These praiseworthy efforts have for the most part been the work of individuals, and as such have only wrought good in particular localities, anything like a combined action being entirely wanting.

Amongst the latest utterances on this vitally important subject, the paper on "Apprenticeship Schools," read by Prof. Silvanus Thompson before the British Association at Sheffield, and just republished in pamphlet form,* and the Address of Prof. Ayrton at the opening of the City and Guilds of London Institute,† are the most striking. The gist of these able contributions to our knowledge of the subject is that our present system of apprenticeship is utterly rotten, and must speedily be replaced, under the penalty of seeing the whole of our trade with foreign nations gradually drift away from us. During the last half century apprenticeship, as it was understood by our forefathers, has ceased to exist except in name. The master of the present day, unlike his predecessors, seeks his own benefit instead of his apprentice's, and looks more to what he can make out of him than what he can teach him. A boy of fourteen enters a workshop, willing and anxious to learn his trade; for the first year or so he finds himself in the position of a mere errand-boy, or at any rate the servant instead of the pupil of his superior. As soon as another apprentice can be found to do his drudgery he is set to some particular branch of work, and if the shop be a large one he will very probably be kept at it till the end of his term. He is placed under a workman from whom he learns but slowly, seeing that his teacher, being constantly employed on his own work, has but little time to teach him,—the evil reaching its highest point in places where piecework is the rule. It is no one's duty to teach him, and, as it formed no part of the contract between employer and employed, the journeyman very justly refuses to expend any very great portion of his time in instructing his master's apprentice in the secrets and mysteries of his handicraft. As for the master, the boy received no help from

* Apprenticeship Schools in France. By Silvanus P. Thompson, B.A., D.Sc., F.R.A.S., Professor of Experimental Physics, University College, Bristol.

† The Improvements Science can effect in our Trades and in the Condition of our Workmen. By Prof. W. E. Ayrton.

him, even supposing that he is competent to teach him. He consequently picks up his knowledge of one small branch of his trade in an unintelligent and desultory manner, and leaves the workshop at the end of seven years capable of doing only one thing, and that by rule-of-thumb, just as his shopmates have done before him. How differently things were managed in what may truly be called the good old days of apprenticeship! In those times the master was also a workman, and labored at his craft. He had learned every branch of it, and understood it so thoroughly as to be able to teach it to others. Capital and steam have together created gigantic factories, and the old domestic workshops—in which each worker formed part of a kind of family—gradually became the exception; the master craftsman became the mere employer, and the apprentice the boy worker.

The connection between the depression of trade in skilled industries and the question of proper technical education, as well as the hopelessness of attempting to galvanize the old system of apprenticeship into life, is well pointed out by Mr. George Howell in the "Contemporary Review" for October, 1877.

The question now is, what modern substitute for the old system can be adopted to the wants and wishes of the nineteenth century? Prof. Thompson's investigations happily enable us to lay before the reader the actual results of certain experiments recently made in France with a view to organizing a new system of apprenticeship that shall be more in accordance with the social conditions of the present day. These results prove that the systematic instruction of apprentices is possible in several different ways; that apprenticeship schools afford a most satisfactory way of attaining this result; and, lastly, that the new system solves the problem involved in the decay of the old apprenticeship. The problem to be solved, briefly stated, is this:—How to give artisan children the technical training and scientific knowledge which their occupation demands, without detaining them so long at school as to give them a distaste for manual labor. The problem may be solved in four ways, all of which have been tested:

First. We may apprentice children at an earlier age than at present, making it obligatory that all through their apprenticeship they shall every day have a certain number of hours of schooling in a school attached to the workshop.

Secondly. The children may be kept at school for a longer period, on condition that they shall pass a certain amount of time in a workshop attached to the school.

Thirdly. We may organize a school and workshop side by side, an equal number of hours being devoted to manual labor and study.

Fourthly. We may send the children for half the day to the existing schools, and the other half to work half-time in the workshop or factory.

The first of these plans strongly commends itself to our attention, for the knowledge imparted in the school could be correlated to the work done in the factory, to the manifest benefit of both the employer and the employed. This system has been tried in France for the last thirty years, and the establishment of MM. Chaix & Co., the French Railway Guide printers, may be cited as a type of the whole. MM. Chaix's typographical school—for such it really is—has been in existence for seventeen years, and has supplied nearly a hundred able workmen to the firm itself, and the few who have left have found exceptionally good situations. The apprentice is bound for four years, the employers guaranteeing him a place when he is out of his time. They are divided into two classes, compositors and printers. Close to the composing and press-rooms there is a school-room, where the apprentices of both classes spend a couple of hours daily, either in improving their knowledge of the three R's or in going through a technical course of typography, including grammar, writing and composition, reading and correcting proofs, the study of the different kinds of type, and so on. They are also taught to read and set up in type Greek and Latin, without any attempt to instruct them grammatically in these languages; and they are taught the rudiments of English and German. Lastly, there is a course on such subjects as the history of typography, or mechanics, physics, and chemistry, as far as they apply to printing machinery and processes. During the three years the apprentice compositors receive from 5*d.* to 2*s.* per day, and the printer apprentices from 7½*d.* to 3*s.* 8*d.* At the end of the term most of the apprentices prefer to remain in the employment of the firm, and can then earn from 3*s.* to 6*s.*, according to their ability. Great pains are taken to systematize the teaching. The compositor apprentices are set to work under the direction of a foreman, whose chief business is to instruct them, and not to work for his own or his employer's benefit; he is, in fact, a professor of printing, just as Professor Thompson is a professor of Physics.

MM. Chaix's establishment, it must be understood, is only one of over two hundred similar schools in different parts of France, in which a similar system of instruction is given in the manufacture of optical instruments, shirts, jewelry, paper, Italian paste, ribbons, calicoes, plate glass, silks, bookbinding, and a dozen other branches of trade.

A great impetus has been given to this kind of apprenticeship schools by the passage of a law, in 1874, forbidding the industrial employment of children under twelve, except they receive two hours schooling per day; nor may children over twelve and under fifteen be employed for more than six hours per day, unless they have finished their elementary education, their employers being made personally responsible for carrying out these regulations.

In the school of M. Soufflot, a jeweler, the character of the instruction is purely technical. The success which has attended the "school on the workshop system," as Professor Thompson aptly calls it, must not only be extremely gratifying to all who have the cause of technical education at heart, but it must also prove to the attentive observer that, being the most natural, it will eventually become the best system of all.

The second type of school includes those in which systematic instruction in one or more handicrafts is given to boys who are still going on with their elementary instruction. There appears to be one school of this sort in Paris, which is carried on most successfully as far as it goes, only about 12 per cent., however, of the pupils receive manual instruction. They work alternately at carpentering, woodturning, forging, filing, chipping, and metal-turning for two years; after which they specialize their work. They also receive instruction in modeling and technical drawing, and in the summer they visit the neighboring factories. On the completion of the preliminary two years they are draughted off into one of the three special workshops in which modeling and carving, carpentry and wood work, and iron and metal work are carried on under the superintendence of master workmen who have made the teaching of their various crafts a special study. One of the disadvantages of this type of school is, that the instruction given is professedly only preparatory to, and not a substitute for, an ordinary apprenticeship. In its favor it must be conceded that it shortens the long and useless years of apprenticeship, and thus helps the young worker to become a bread winner.

The third system is where the school and the workshop are placed side by side, so that the hours given to study should be co-ordinated with an equal number of hours of manual instruction. This type of school Prof. Thompson thinks is the *apprenticeship school* of the future. France affords two good examples of this class; one the Paris Municipal School of Apprentices, where several distinct trades are taught; and the Besancon Municipal School of Horology, where clock and watch making alone are taught. Taking the Paris school first, we find that the apprentices are only admitted between the ages of thirteen and sixteen. They must also have a certificate showing that they have completed their elementary education, or else undergo an examination. In comparison with schools of the second type a larger amount of time is devoted to the workshops, which are here much more extensive and complete. The course is a three years' initiation into the handicraft taught, and the majority of the pupils leave the school able workmen. The trades in which direct instruction is given are those of the carpenter, wood turner, pattern maker, smith, fitter and metal burner. That the school turns out excellent workers may be judged from the fact that the average age of the pupils who left the school in 1877 was $17\frac{1}{2}$ years, and their average earnings in the places they had obtained was 3*s*. $1\frac{1}{2}$d. per day, one boy of seventeen getting as much as 5*s*. $4\frac{1}{2}$*d*. per day as a smith. The instruction is entirely gratuitous, and the whole of the necessary tools, machines, books, etc., are supplied by the Municipality. The system pursued in the school appears to be of the very highest order, and should serve as a model for all future schools of the kind. The Besancon School of Horology is managed on similar principles, and is a striking success. The school is managed and supported entirely by the Besancon Municipality. In addition to instruction in every branch of horology, the apprentices receive lessons in their own language, arithmetic, algebra, geometry, physics, chemistry, mechanics and drawing, in so far as they relate to horology.

The only system remaining for consideration is that of half-time schools; the system has, however, been almost discarded in this country, and has only been partially tried in France. One radical defect in it is, that there is no correlation between the work done in the factory and the information imparted by the schoolmaster; the whole of the pupils, whether they are intended to be mechanics, dyers or painters, all receive the same kind and quantity of instruction.

So much for the good work that is being done in France, which of all European nations is certainly in the van with regard to lower technical education.

In September last Prof. Thompson visited Germany in compliance with the advice of Mr. Mundella, who, in criticising his paper at the British Association, placed the German technical schools above the French. Prof. Thompson paid visits to the Polytechnicum and Weaving Schools at Chemnitz, these being the special establishments pointed out by Mr. Mundella, and found, as he expected, that although the higher technical training schools in Germany were superior to those elsewhere, they could show nothing in any way equal to the Paris Municipal Apprentice School described above.

Prof. Thompson's investigations have been so thorough, and led to such practical conclusions, that they should receive the serious consideration of those whose business it will be to organize either national or local systems of technical education.

The movement of the city companies has resulted in the setting aside annually of £15,000 for the promotion of technical education, and there has been duly constituted "The City and Guilds of London Institute for the Establishment of Evening Classes for Technical Education, or the Application of Science to Industry." Twelve lectures on "Some of the Practical Applications of Electricity and Magnetism," by Mr. W. E. Ayrton, A.M., Inst. C.E., and twelve lectures on "The First Principles of Chemistry," by Prof. H. E. Armstrong, Ph.D., F.R.S., are now in course of delivery. Subsequent courses of lectures on "The Elementary Principles of Mechanics exemplified in our Clocks and Watches," on "The Applications of the Laws of Heat to the Steam and other Engines," and on "Inorganic Chemistry with especial reference to its Technical Applications," have already been arranged.

We trust this example will be followed in our large manufacturing towns, and that when the best system of imparting technical education has been determined, no red tapeism will hinder it from being speedily and universally adopted. England will then soon regain her former position. Even the Japanese have, as Mr. Ayrton remarks, set us an example that our ambition should lead us to emulate. There has grown up, in the very midst of a people who a few years ago were almost in a state of slavery, a technical college, with its staff of carefully chosen English professors, with its laboratories, class-rooms, museums, libraries and workshops, costing for maintenance an annual sum of £12,000. To study at this college neither money nor position is necessary; ability and a desire for knowledge are the only qualifications.

BOXWOOD IN RUSSIA.—Boxwood grown in the forests on the shores of the Caspian Sea, is, says the *Gardener's Chronicle*, a large article of trade with Russia. This wood reaches Astrachan and Nizni-Novgorod in the spring of the year, where it is sold during the fair. Last year the quantity so sold was about 130,000 poods, being about 80,000 poods in excess of other years. It is pointed out in a recent report that the increased demand for this boxwood, which is used for shuttle-blocks, indicates increased prosperity among Russian manufacturers. On the subject of boxwood, the acting British Consul at Tiflis writes: "*Bona fide* Caucasian boxwood may be said to be commercially non-existent, almost every marketable tree having been exported. Such exorbitant terms are demanded by the government for the right of cutting in one or two remaining Abkhasian boxwood forests as virtually to bar their acquisition." He goes on to say that having personally visited these forests he is in a position to assert that their real value has been considerably exaggerated, most of the trees being either hollow or knotted from age, and much of the best wood having been felled by the Abkhasians previous to Russian occupation. The boxwood at present exported from Rostov, and supposed to be Caucasian, comes from the Persian provinces of Mazanderan and Ghilan on the Caspian. What has been said respecting boxwood applies equally to walnut burrs, or "loupes," for which the Caucasus was once famous, 90 per cent. of which now come from Persia. The walnut trees of the forest along the Black Sea, which are extraordinarily numerous, and afford excellent material for gunstocks, do not, from some climatic peculiarity, produce burrs, which are only found in the dryer climates of Georgia, Daghistan, Persia, &c. The immense quantity of walnut timber in the forests on the Black Sea is mostly unavailable from the complete absence of roads or means of transport, and the dearness and scarcity of labor.

REPORTS OF ENGINEERING SOCIETIES.

The American Society of Civil Engineers.—The December number of "Transactions" is at hand.

Its pages are mostly filled with discussions of paper No. 180, "On the Construction and Maintenance of Roads" by Edward P. North.

A valuable note on the "Nomenclature of Bitumens" by Mr. North is added; also some illustrations of various forms of Stone Crushers.

The Engineers' Club of Philadelphia.—During the past year the membership has been largely increased, the Club has moved into new and commodious rooms, and the experiment of publishing Proceedings has proved highly satisfactory. The library has been largely increased by contributions from members, authors and publishers, and there have been received in exchange for the "Proceedings" copies of reports and proceedings of nineteen engineering societies and the current numbers of twenty-one periodicals, including all the principal engineering magazines.

The tellers appointed to supervise the annual election reported the following gentlemen elected officers of the Club for 1880:

President—Mr. Frederick Graff.
Vice-President—Mr. Percival Roberts, Jr.
Recording Secretary—Mr. Wilfred Lewis.
Corresponding Secretary and Treasurer—Mr. Chas. E. Billin.
Board of Directors—Mr. Rudolph Hering, Mr. Coleman Sellers, Jr., Mr. Howard Murphy, Mr. Geo. Burnham, Jr.

Liverpool Engineering Society.—The usual fortnightly meeting of this society was held at the Royal Institution, Colquitt street, on Wednesday evening last, the 5th inst., Mr. M. E. Yeatman, M. A., president, in the chair, when a paper, entitled "Notes on Sewers and Sewage," was read by Mr. E. H. Allies, Member of the Association of Municipal and Sanitary Engineers and Surveyors. The author divided his subject into four parts: (1) Drainage works both ancient and modern; (2) the sewer in its relation to public health; (3) the form, construction, and ventilation of sewers; and (4) the disposal of sewage. After glancing at the construction of sewers by the Romans and others down to our times, the author went on to show how great an effect the sewer had on public health, and how important it is that work of this description should be properly designed, carried out, and kept in repair. He treated at considerable length of the ventilation of sewers, and the various methods proposed from time to time for effecting this object, advocating the system of open grid ventilators at frequent intervals, and condemning the use of charcoal in lever ventilators. In conclusion he treated of the disposal of sewage, and showed how the difficulty of dealing with this part of the question has increased of late years. The author does not believe in any of the chemical treatments of sewage being made to pay at present, in proof of which he stated that at least nineteen-twentieths of the sewage of Great Britain is still thrown away. He advocated agricultural irrigation as the least expensive mode of disposing of town sewage when there is no direct outlet to the sea, and gave the area required for this purpose per head of population.

The Institution of Civil Engineers.—The Council of the Institution of Civil Engineers have awarded the following premiums for the session 1878-79:

FOR PAPERS READ AT THE ORDINARY MEETINGS.

1.—A Watt Medal, and a Telford Premium, to George Frederick Deacon, M. Inst. C.E., for his paper on "Street Carriage-way Pavements."

2. A Telford Medal, and a Telford Premium,

to John Bower Mackenzie, M. Inst. C.E., for his paper on "The Avonmouth Dock."

3.—A Watt Medal, and a Telford Premium, to James Nicholas Douglass, M Inst. C.E., for his paper on "The Electric Light applied to Lighthouse Illumination."

4.—A Telford Medal, and a Telford Premium, to Adam Fettiplace Blandy, M. Inst. C.E., for his paper on "Dock Gates."

5.—A Telford Premium, to Edward Dobson, Assoc. M. Inst. C.E., for his paper on "The Geelong Water Supply, Victoria, Australia."

6.—A Telford Premium, to James Price, M. Inst. C.E., for his paper on "Movable Bridges."

7.—A Telford Premium, to John Evelyn Williams, M. Inst. C.E., for his paper on "The Whitehaven Harbor and Dock Works."

8.—The Manby Premium, to John Purser Griffith, Assoc. M. Inst. C.E., for his paper on "The Improvement of the Bar of Dublin Harbor by Artificial Scour."

FOR PAPERS PRINTED IN THE PROCEEDINGS WITHOUT BEING DISCUSSED.

1.—A Watt Medal, and a Telford Premium, to George William Sutcliffe, Assoc. M. Inst. C.E., for his paper on "Machinery for the Production and Transmission of Motion in the Large Factories of East Lancashire and West Yorkshire."

2.—A Watt Medal, and a Telford Premium, to Edward Sang, for his paper on "A Search for the Optimum System of Wheel Teeth."

3.—A Telford Premium, to William George Laws, M. Inst. C.E., for his paper on "The Railway Bridge over the River Tyne at Wylam, Northumberland."

4.—A Telford Premium, to George Higgins, M. Inst., C.E., for his "Experiments on the Filtration of Water, with some Remarks on the Composistion of the Water of the River Plate."

FOR PAPERS READ AT THE SUPPLEMENTAL MEETINGS OF STUDENTS.

1.—A Miller Prize, to Arthur Cameron Hurtizg, Stud. Inst. C.E., for his paper on "The Tidal Wave in the River Humber."

2.—A Miller Prize, to Robert Henry Read, Stud. Inst. C.E.. for his paper on "The Construction of Locomotive Boilers."

3.—A Miller Prize, to John Charles Mackay, Stud. Inst. C.E., for his paper on "The Excavation of a Tunnel in Rock by Hand Labor and by Machinery.

4.—A Miller Prize, to Percy Wilson Britton, Stud. Inst. C.E., for his paper on "The Design and Construction of Wrought Iron Tide Arches."

IRON AND STEEL NOTES.

The yield of iron ore in the kingdom of Prussia during the past year was 2,955,872 tons, raised from 549 pits, and employing 21,991 hands. The number of charcoal furnaces is 44, of which 33 were in blast during 1878, the consumption of home ore being 74,013 tons, and of foreign ore 1,370 tons. The production of pig from these charcoal furnaces was 14,192 tons. The coal and coke furnaces numbered 184, of which 128 were in blast. The yield from these was 1,534,830 tons of pig, of which 54,983 were foundry pig, 426,816 Bessemer pig, open-hearth pig, and spiegeleisen, and 1,040 830 mill pig. Two furnaces have also been running on mixed fuel, making the total pig iron production for the year 1.568,061 tons, smelted in 163 furnaces, and employing 12,992 hands. There were also 571 foundries, employing 19,415 men. Wrought iron is made in 264 establishments, employing 36,540 men, and the production was 1,123,171 tons. In the steel trade, 25 out of the Bessemer converters were in operation during the year, together with 442 open-hearth furnaces and 25 crucible furnaces. The total production of Bessemer steel was 452,399 tons, and of open-hearth steel 51,731 tons. The crucible steel trade was stagnant during the year, only 74 crucibles being in operation out of 282 existing.

Nitrogen in Steel.—Whether nitrogen is an essential, or even an occasional, constituent of steel, is a question which has not yet been settled; and after recounting what has been done by previous investigators, the author describes the method of procedure which he prefers. The process has consisted in dissolving the steel in hydrochloric acid in an apparatus from which the air had previously been completely expelled In this manner any combined nitrogen in the metal would be converted into ammonia, which would partly remain dissolved in the liquid and partly pass off with the hydrogen evolved. Any loss from the latter cause was avoided by passing the evolved gas through a tube filled with glass beads moistened with hydrochloric acid. When the solution of the metal was complete, the liquid was distilled with excess of quicklime, and the ammonia in the distillate determined by Nessler's method. This extremely delicate test for ammonia was unknown at the date of previous researches on the existence of nitrogen in steel. Its employment enabled Mr. Allen to operate on a much smaller quantity of steel than was used by previous operators, and it facilitates the operation in every way. Very special precautions were taken to obtain the hydrochloric acid and other materials free from any trace of ammonia or nitrous compounds, and it was directly proved by experiments that no source of ammonia existed in the reagents or apparatus. On determining in this manner the nitrogen in samples of commercial steel and iron, more or less nitrogen has, so far, always been found, varying in most instances from 0.005 to 0.015 per cent. of the weight of the metal, amounts which would be wholly overlooked by many methods of working.

Methods of Hardening Iron and Steel.—Experience has shown that the effect of hardening mainly depends upon the content of combined carbon in the iron, upon the differences of temperature between the iron or steel and the hardening fluid, and further on the rapidity of the cooling. The last-mentioned again is dependent on the quantity of the hardening fluid, its specific gravity, power of conducting heat, specific heat, boiling point, and heat of vaporization. Of the four liquids, mercury, water, oil, and coal-tar, therefore, the first-named hardens much more powerfully than water, water considerably more powerfully than oil, and oil more powerfully than coal-tar. Further, the hardening power of water is altered not only by differences of temperature, but also by the addition of different substances which change its properties in the respects just mentioned. Finally, the rapidity of cooling, so important for the degree of hardening, is also dependent on the way in which the piece is held down into the hardening fluid. The rapidity of the first cooling, from the 600 deg. to 700 deg. C., to which steel has commonly been heated to 300 deg. to 400 deg. C., has a manifold greater influence on the degree of hardness than the succeeding cooling to, say, 60 deg.

RAILWAY NOTES.

The Gothard tunnel heading was, on January 1st, within little more than 400 meters of completion; but the difficulties encountered during the last few weeks, owing to faults and to influx of water, will very considerably retard the junction of the two headings. It seems that a bed of soft material which has been met with in the tunnel is causing the most trouble by its exudation and transmission of the pressure as by a semi-fluid due to the super-incumbent rock masses.

Railway Accidents.—The Board of Trade has issued a summary of the accidents and casualties which have been reported to the Board as having occurred upon the railways in the United Kingdom during the nine months ending September 30, 1879. The number of persons killed and injured during that period was as follows: Passengers—From accidents to trains, rolling stock, permanent way, etc., 412 injured; by accidents from other causes, 53 killed, 470 injured. Servants of companies or contractors—From accidents to trains, rolling stock, permanent way, etc., 2 killed, 73 injured; by accidents from other causes, 303 killed, 1,286 injured. Persons passing over railways at level crossings, 46 killed, 19 injured; trespassers, including suicides, 224 killed, 98 injured; other persons not coming in the above classification, 27 killed, 62 injured—Total, 655 killed, 2,420 injured. In addition to these, the railway companies have reported to the Board of Trade, in pursuance of the 6th section of the Regulation of Railways Act, 1871, that 31 persons were killed and 1,586 injured upon their premises, but in these accidents the movement of vehicles used exclusively upon railways was not concerned. Thus, the total number of personal accidents reported to the Board by the several railway companies during the nine months amounts to 686 persons killed and 4,006 injured. Accidents to trains, rolling stock, permanent way, etc , caused the death of three persons and injury to 485, viz., passengers, injured, 412: servants of companies, killed, 2; injured, 73; other persons, killed, 1. During the nine months there were reported 24 collisions between passenger trains or parts of passenger trains, by which 98 passengers and 5 servants were injured; 55 collisions between passenger trains and goods trains or mineral trains, engines, etc., by which 1 servant was killed and 166 passengers and 22 servants were injured; 15 collisions between goods trains or parts of goods trains, by which 18 servants were injured; 61 cases of passenger trains or parts of passenger trains leaving the rails, by which 39 passengers and 3 servants were injured; 6 cases of goods trains or parts of goods trains, engines, etc., leaving the rails, by which 1 servant was injured; 7 cases of trains or engines traveling the wrong direction through points, by which 34 passengers and 6 servants were injured; 13 cases of trains running into stations or sidings at too high a speed, by which a man who had come to a station on business was killed and 58 passengers and 2 servants were injured; 3 cases of the bursting of boilers, or tubes, etc., of engines, by which 1 servant was killed and 5 were injured; 937 failures of tires, by which 2 servants were injured; 346 failures of axles, by which 3 passengers and 2 servants were injured; 13 failures of couplings, by which 7 passengers were injured; 2 failures of ropes used in working inclines, by which 1 servant was injured; 1,377 broken rails, by which 1 passenger and 3 servants were injured; 21 slips in cuttings or embankments, by which 3 servants were injured; and 5 other accidents, by which 6 passengers were injured. Under the heading of accidents to passengers from causes other than accidents to trains, rolling stock, permanent way, etc., including accidents from their want of caution or misconduct, accidents to persons passing over level crossings, trespassers, and others, it appears that 349 persons were killed and 649 were injured, and that 53 of the killed and 470 of the injured were passengers. Of the latter, 17 were killed and 44 injured by falling between carriages and platforms, viz., 9 killed and 30 injured when alighting from and 8 killed and 14 injured when getting into trains; 5 were killed and 320 injured by falling on to platforms, ballast, etc., viz., 5 killed and 290 injured when alighting from and 30 getting into trains; 14 were killed and 6 injured while passing over the line at stations; 42 were injured by the closing of carriage doors; 8 were killed and 22 injured by falling out of carriages during the traveling of trains; and 9 were killed and 36 injured from other causes; 46 persons were killed and 19 injured while passing over railways at level crossings, viz., 30 killed and 15 injured at public level crossings; 12 killed and 3 injured at occupation crossings, and 4 killed and 1 injured at foot crossings; 184 persons were killed and 98 injured when trespassing on the railways; 40 persons committed suicide on railways; and of other persons not specifically classed, but mostly private people having business on the companies' premises, 26 were killed and 62 injured. During the nine months there were 303 servants of companies or contractors reported as having been killed and 1,286 injured, in addition to those included in the first category of accidents.

The surveys for the proposed railway over the Brunig are now complete, and the work will probably soon be taken in hand. The line will start from Brienz, and run by Meyringen and the Brunig Pass to Garnen, Alpnach, and Staad, on the Lake of the Four Cantons. The steepest gradient will be 12 in 100, the total length of the line will be twenty-five miles, and by the adoption of a gauge of one meter and the avoidance of tunnels, it is estimated that the cost of construction will not exceed £10,000 per mile.

ORDNANCE AND NAVAL.

HER MAJESTY'S SHIP "MERCURY."—The new steel despatch vessel Mercury, which is being completed for sea at Portsmouth, was tried under way on three days in August, the first day being devoted to power and the others to speed.

In material, construction and dimensions, and in the power and description of her machinery, the Mercury is a sister ship to the steel despatch vessel Iris, which has completed her trials at Portsmouth and is ready for commissioning. The only difference has reference to appearance and is a mere matter of detail of no practical importance. The Iris has an overhanging bow, a figure-head being placed on what is termed the "knee of head," while the Mercury has a perfectly straight stem. She was built at Pembroke from Mr. Barnaby's designs, and is engined by Messrs. Maudslay, Sons & Field. As was the case with the sister ship, everything has been surrendered in the Mercury in order to secure a high rate of speed. She is entirely unprotected, her entrance and run are as fine as a racing yacht, and her machinery, which fills the major portion of the hull, is guaranteed to develop 7,000 on her trial trip. She is built of Landore mild steel, and measures 300 feet between perpendiculars, 46 feet 1 inch in extreme breadth, 16 feet 3 inches in hold, and has a displacement of 3,750 tons. Her armament will consist of ten 64-pounders, including a couple of revolving chase guns, which will be mounted on the forecastle and the poop. The engines for working the twin screws are a novelty, so far as the navy is concerned, and are located in separate engine-rooms, divided by a water-tight doorway, the starting platforms of each pair of engines being situated conveniently close to the door. There are in all four high-pressure cylinders, having a diameter of 41 inches, and four low-pressure cylinders, with a diameter of 75 inches, the stroke being 3 feet. Each of the former is bolted to the front of the low-pressure cylinder with which it works, and, for the sake of economizing space, is partly recessed into it. One piston rod carries the two pistons, an arrangement which has been found the best adapted for working at high rates of expansion without any jolting of the moving parts. Each engine, however, is complete in itself, and can be used as a single engine in case of injury to its companion.

This trial can scarcely be said to possess the same interest for engineers as the experimental cruises of the Iris in 1877-8. Built on the same lines and engined in precisely the same manner as her predecessor, her performances under defined conditions of power and screw could have been well-nigh foretold. The Iris was tested under way with four varieties of twin propellers, and the screws which have been fitted to the Mercury are the four-bladed screws of the third series of experiments which gave a speed of 18.57 knots, with 7,714 of indicated horse power. These results, it is true, so far as speed on the measured mile was concerned, were subsequently surpassed by the works of a special two-bladed screw, which gave 18.587 knots, with 7,556 indicated horse power, but the small improvement in speed under full power did not compensate for the increased vibration produced throughout the ship at all speeds except the maximum. No. 3 screws were, therefore, adopted, though, had time permitted, it was Mr. Wright's intention to continue the experiments. The diameter was 16 feet 3½ inches, while the pitch at the forward edge of the blades was 18 feet 11½ inches, at the after edge 20 feet 11½ inches, and the mean pitch as measured 19 feet 11½ inches. The disc area of the blades was .288 of the whole disc. The blades were curved aft a little towards the tips, with a view of keeping the points rather further away from the A brackets, and of checking, in some degree, any centrifugal tendency of the water acted upon. The blades, which were constructed of gun-metal, were polished on both sides to reduce friction, and the edges were made sharp. The original bosses to which the blades were attached had each a conical tail-piece added. The vessel left the Tidal Basin at half-past 7 o'clock for a six hours' continuous full power trial, and after clearing the harbor the engines were gradually worked up to full speed. The trial commenced at a quarter past 8, a run being made down the Channel as far as St. Alban's Head. The force of the wind was from 3 to 4, and the direction abeam, the sea being quite smooth at the time. The draught was 15 feet 8 inches forward and 20 feet 6 inches aft, which was precisely the trim of the Iris during her experimental trips. At the preliminary run the mean pitch of the screw was fixed at 20 feet 8 inches, from which 7,025 horse power was realized. This was so far satisfactory, as the result showed 25 horses over the contract; but, as the engines could not take all the steam that was generated, and still better results were expected, the Mercury was subsequently docked and the pitch confined to 20 feet, which, again, was the pitch of the Iris's fans in the trial to which allusion has already been made. Singularly enough, the engines could have taken more steam than could be obtained, the mean number of revolutions per minute having increased from 91 to 95.

The results were scarcely as satisfactory as at the preliminary trial, for while some of the observations showed that the engines were indicating 7,396 and 7,268.6 horses, the mean of the whole run gave a total indicated power of 6,953.07 (that is, 3,514.14 by the starboard and 3,438.93 by the port engines), or a little below the guaranteed power. It will be seen that only on two occasions did the pressure in the boilers reach 65 lbs., to which the safety-valves were loaded, while near the end of the trial the pressure fell as low as 58 lbs. The cause of this was undoubtedly a failure in the supply of the smokeless coal which is generally used on steam trials and the necessity for resorting to North-country coal. By these means not only was the heat in the furnaces reduced, but the tubes partly choked by the thick smoke. The vacuum was exceedingly regular and satisfactory, the mean being 27.43 inches in the starboard and 27.14 inches in the port condensers. The other means were:—Steam in starboard cylinders, 39.737 and 11.087 lbs.; and in port cylinders, 39.341 and 10.85 lbs.; revolutions, 95.5 starboard, and 94.5 port. A mean of a couple of runs on the mile in Stokes Bay gave a speed of 18.055 knots. These runs were made during the 10th and 11th half hours, when the steam pressure was low, and when the feed to the boilers had become somewhat irregular. (The coal consumption averaged 2.35 lbs. per indicated horse power per hour.) The steam steering gear was found to act admirably, one man being able to steer the ship, where otherwise sixteen would be required to get the rudder over 15 degrees. By steam power the helm is put hard over 24 degrees. In the course of the day Mr. Wright took observations of the obstruction produced by the struts of the propeller tubes, which are not in the same plane with the water.

Although the Government officials were well satisfied with the working of the engines during the six hours' run, it was thought desirable to try the ship for speed on the measured mile, and thereby institute a comparison between her performances and those of the Iris. This trial was made on Thursday, and led to some astonishing results. The day was exceedingly boisterous, the wind having the force of between five and six, and the sea rather rough. The direction of the wind was west-south-west, and thus almost directly ahead and astern during the runs in Stokes Bay. Staff-Commander Parker was the officer in command, the other officials, with the exception of Mr. Wright, who was not present, being the same as on the previous day. After an hour's preliminary cantering, the ship was placed upon the mile with the following results, the boiler pressure being 64.75 lbs.:—

	Revolutions.	I.H.P.	Knots.
First Mile.....	97	7471.09	18.274
Second Mile...	98	7451.78	19.149
Third Mile....	97	7537.97	18.848
Fourth Mile...	98	7594.98	18.750

The mean of all the means gave the remarkable speed of 18.876 knots per hour, thereby beating the Iris (which realized a mean speed of 18.54 knots), and proving the Mercury to be the swiftest full-sized ship afloat in any navy of the world. Indeed, it is difficult to conceive of a ship of her size being driven through the water at the rate of close upon 22 miles an hour. The horse power developed was also more than satisfactory, since the mean reached a total of 7,513.95, which is greatly in excess of the contract, the mean revolutions per minute being 93.44 starboard and 97.26 port, and the average vacuum, 27.5 starboard and 27.12 inches port. The engines were subsequently worked with the jet injection, the results obtained being 4,214.92 horse power, 80 revolutions and a vacuum 25 and 23.5 inches. The exhaust into the low-pressure cylinders was next cut off, and all the eight cylinders worked direct from the boilers, as common engines, for the purpose of ascertaining with how low a pressure the machinery could be worked in action. The pressure in the boilers was reduced to 60 lbs. above the atmosphere, and was then gradually further diminished to the atmospheric pressure. Under the latter conditions 60 revolutions were obtained. The engines were next stopped, and started again at 5½ lbs. above the atmospheric pressure; and were afterwards worked at full power to bring the ship into harbor. Before the close of the trial, however, the engines were stopped, the starboard engine in 34 seconds and the port in 37 seconds, being stopped they were started ahead in 12 seconds and 10 seconds respectively; and going astern they were started ahead in 17 seconds and 10 seconds. The whole of the second day's steaming proved a gratifying success.

BOOK NOTICES.

Rough Ways Made Smooth. By R. A. Proctor. London: Chatto & Windus, 1880. For sale by D. Van Nostrand. Price, $2.25.

We have here another series of Mr. Proctor's lively and popular essays on subjects multiform and mix, ranging in the present instance from the Sun's Corona and his Spots and the Past History of the Moon, to Oxford and Cambridge Rowing and Mechanical Chess Players. Whatever may be thought of the author's theories and antipathies, there can only be one opinion as to the felicity of his method. Some of the matters treated of are among the most abstruse; but they are presented in such a way as to be easily understood by, as well as interesting to, the ordinary run of mortals. In the paper on electric lighting we have a popular account of the principles and apparatus of one of the most attractive inventions of the day, and one which has apparently more than most excited the popular imagination. That on mechanical chess-players is also well worth perusal, and one or two psychological questions are ably handled, while the articles on Cold Winters and Great and Recent Storms, have the additional merit of being opportune.

A Textbook of Field Geology. By W. H. Penning, F.G.S. Second Edition. London: Balliere, Tindal & Cox, 1879. For sale by D. Van Nostrand.

The author of this text-book, who is engaged on the Geological Survey of England and Wales, possesses special qualifications as an instructor of geological amateurs who wish to extend their investigations beyond mere fossil-hunting, and to test geological theories by practical observations in the field. To be able to do this is to have acquired an accomplishment that gives a peculiar charm to every country ramble, turning the landscape itself into a book in which its ancient history can be read. The instructions given are very full and complete, the *instrumenti belli* are described, and their uses explained. The mode of geological surveying is set forth in detail, including divers "wrinkles" as to the way of readily getting at desiderated information when it does not appear exactly on the surface, as well as map-making and the identification of rocks by their lithological structure. Where fossils, the "medals of creation," occur, the student will find ample guidance in the appended section on Palæontology by Mr. A. J. Jukes Browne, who treats of the nature of fossil remains, instructs how to collect them, and shows the nature and importance of the information they supply. In the concluding section the importance of field geology is enforced, certain difficulties connected with it discussed, and its practical results shown. The illustrations of the volume include a colored geological map and a number of sections and diagrams.

Torpedoes and Torpedo Warfare: Offensive and Defensive. Being A Complete History of Torpedoes and their application to Modern Warfare. By C. Sleeman, Esq., late Lieutenant R.N., and late Imperial Ottoman Navy. New York: D. Van Nostrand. Price, $8.

This is an entirely new book, on a subject about which the public at times feel an absorbing interest, and which never ceases to attract the attention of military men everywhere.

How fully this treatise represents the present state of progress in torpedo making, the following table of contents will perhaps sufficiently indicate:

Chapter I.—The early History of the Torpedo—Remarks on the existing state of Torpedo Warfare.

Chapter II.—Defensive Torpedo Warfare—Mechanical Submarine Mines—Mechanical Fuzes—Mooring Mechanical Mines.

Chapter III.—Defensive Torpedo Warfare, continued—Electrical Submarine Mines—Electrical Fuzes—Insulated Electric Cables—Electric Cable Joints—Junction Boxes—Mooring Electrical Submarine Mines.

Chapter IV. Defensive Torpedo Warfare, continued—Circuit Closers—Firing by Observation—Voltaic Batteries—Electrical Machines—Firing Keys and Shutter apparatus—Testing Submarine Mines—Clearing a passage through Torpedo Defences.

Chapter V.—Offensive Torpedo Warfare—Drifting Torpedoes—Towing Torpedoes—Locomotive Torpedoes—Spar Torpedoes—General Remarks on Offensive Torpedoes.

Chapter VI.—Torpedo Vessels and Boats—The "Uhlan"—The "Alarm"—The "Destroyer"—Thornycroft's Torpedo Boats—Yarrow's Torpedo Boats—Schibau's Torpedo Boats—Herreshoff's Torpedo Boats—Torpedo Boat Attacks—Submarine Boats.

Chapter VII.—Torpedo Operations—The Crimean War (1854-1856)—The Austro-Italian War (1856)—The American Civil War (1861-1865)—The Paraguayan War (1864-1868)—The Austrian War (1866)—The Franco-German War (1870-1871)—The Russo-Turkish War (1877-1878).

Chapter VIII.—On Explosives—Definitions—Experiments—Gunpowder—Picric Powder—Nitro-Glycerine—Dynamite—Guncotton—Fulminate of Mercury—Dualin—Lithofracteur—Horsley's Powder—Torpedo Explosive Agents—Torpedo Explosions.

Chapter IX.—Torpedo Experiments—Chatham, England, 1865—Austria—Carlscrona, Sweden, 1868—Kiel, Prussia—England, 1874—Copenhagen, Denmark, 1874—Carlscrona, Sweden, 1874-5—Portsmouth, England, 1874-5—Pola, Austria, 1875—Portsmouth, England, 1876—Experiments with Countermines—The Medway, England, 1870—Stokes Bay, England, 1873—Carlscrona, Sweden, 1874.

Chapter X.—The Electric Light—The Nordenfelt Torpedo Guns—Diving.

Chapter XI.—Electricity.

Appendix.—McEvoy's Single Main Systems—Siemans' Universal Galvanometer Tables—Synopsis of the principal events that have occurred in connection with the History of the Torpedo—Index.

The work is a large octavo with fifty-seven full page illustrations, besides numerous woodcuts.

Sewers and Drains for Populous Districts. By Julius W. Adams. New York: D. Van Nostrand. Price, $3.00.

No branch of engineering is so intimately related to the health and comfort of the residents of large towns, as that of drainage, yet the literature pertaining to it is by no means abundant. There has been no deficiency in general and vague suggestions as to what is desirable in the treatment of sewage, and much confusion of mind will result from reading a collection of the accepted authorities upon this topic; but of the method of solving the problem of efficient *drainage*, stated so as to prove serviceable to the young engineer, too little has thus far been written to satisfy the wants of the profession.

The reason of the deficiency is upon reflection quite obvious. The subject is one that can only be justly treated by a professional engineer of unusual sagacity, and of a ripe and rare experience. Without these qualifications, the ability to write upon engineering subjects, or to wield skillfully the most refined methods of mathematical analysis, lead in this field of labor to no useful results. The final formulas are of necessity in the strictest sense empirical.

Col. Adams has unquestionably brought to bearupon this work the order of talent necessary for a serviceable guide for the profession. In beginning he thus states the problem:

"The modern system of sewage contemplates the construction of a system of impermeable conduits, which, with the water supply to dwellings, and at times the rainfall on the surface, shall prove adequate to the prompt removal from the sites of human habitation, and before time shall be afforded to set up any dangerous fermentation, all excretæ and refuse from human, animal, or vegetable life—everything, in fact, putrescible to be found in the vicinity of dwellings—to some outlets, to be further dealt with by natural or artificial means in order that they may not prove a source of mischief to the residents of other localities.

This method is known as the 'water-carriage system'; and as the solid fæces adds no appreciable amount to the bulk of the house-sewage, so the house sewage calls for no appreciable increase in the capacity of the sewer to carry it off, beyond such as is necessary for the accommodation of that amount of the storm-waters as modern improvements in habitations requires to be carried off in a definite time. This eliminates the consideration of the extent of the population on an area to be drained, and leaves the dimensions of the sewers to be controlled measurably by consideration of the character and extent of that area. Closely-built and paved districts will affect the result only so far as contributing the proportion of the rainfall due to its area in less time after its fall than that from suburban districts. The further consideration of this in its bearing on the dimensions of sewers will be noted subsequently.

The points which demand our attention may be stated as follows:

First.—The area and physical outlines and controlling features of the district to be drained; its geological character, and the depth to which it may be desirable that the drainage should extend.

Second.—The rainfall in the district, with consideration of the maximum fall of rain in a given interval of time, and the proportion of such storm-waters as it is proposed to carry off by the sewers.

Third.—The character and extent of the water supply.

Fourth.—The final disposal of the sewage."

Each of these "points" is treated fully but concisely. There is no lack of clearness in the writer's statement of his deduction from observation, nor does he obscure his mathematical formulas by any devices of integration. Nothing can be plainer than the processes employed or than the reasons for them.

The question of house drainage receives its share of attention, and is well illustrated.

The work deserves, and will doubless receive, a wide circulation.

A Treatise on Fuel, Scientific and Practical. By Robert Galloway, M.R.I.A., F.C.S., &c. London: Trübner & Co. 1880. For sale by D. Van Nostrand. Price, $1.50.

This volume is founded on a course of lectures delivered by the author during his professorship in the Royal College of Sciences, Dublin, and is intended for advanced students and for manufacturers. It is, perhaps, not difficult to trace the part which was originally published in the lecture-room, and which shows that Professor Galloway possesses the rare art of popularizing science; but that elementary portion has been supplemented by much valuable matter of a more practical character, and the resulting handbook cannot fail to be useful to all to whom its subject is of interest, either theoretically or economically. All the substances employed as fuel consist almost wholly of woody tissue, the tissue of recent vegetation being unaltered, and that in peat and the different varieties of coal being in a more or less altered form. Recent timber, and even the stems of grasses, are employed to a considerable extent, in this and other countries, to produce motive power; peat is less frequently used, and it, as well as coal, is employed in the production of charcoal or coke. The former, however, cannot be economically substituted for coal in this country, owing to its bulky nature and the water it retains, even after being thoroughly air-dried. The most important of all fuels, coal, varies very much in character. Some of it approachee very closely to recent wood; other varieties, again, contain so much extraneous matter, as, for example, the Torbane mineral, that their right to be called coal is disputed. Even the most bituminous coals differ in composition so greatly, that for important manufacturing purposes some of them are almost as valueless as peat. Coking coal, for instance, is inapplicable for many furnace operations from its choking up the bars and thus impeding combustion, and where coal contains much pyrites, besides other drawbacks, it corrodes the furnace bars. Lignite is a late deposit, varying in physical character from that of the more compact peats to that of the bituminous coals, which are the most valuable and abundant of all. These, again, are divided into caking or coking, and free-burning coals. Cannel coal, to which division the Torbane mineral already referred to belongs, contains a large proportion of hydrogen and other volatile matter. Anthracite, which is found in the lowest portion of the carboniferous formation, is a species of natural coke, containing 90 per cent. or more of carbon. Coal always contains in its pores a variable quantity of gas. That in the Welsh steam-coal is highly inflammable, and evolved to a great extent after the coal has been raised, hence the danger of carelessly shipping it. The decomposition, which allows the gas thus to escape, has been generally attributed to the oxidation of iron pyrites contained in the coal. Professor Galloway agrees with Dr. Percy that it is rather due to the oxidation of the organic substances of the coal itself. Chapter II. is devoted to an elaborate exposition of the methods employed for determining the heating power of fuel, and the instruments used for that purpose; and the author afterwards shows that from causes specified, the total theoretical heating power is never obtained in practice. In the two succeeding chapters the principles of construction of pryometers and Siemens' regenerative gas-furnaces are lucidly described, the technical examination and analysis of coal are explained, and a description of Orsat's gas apparatus is given, with the tables employed in calculating the results.

A Treatise on Mountain Roads, Live Loads and Bridges. By Lieut.-Gen. H. St. Clair Wilkins, R.E. London: E & F. N. Spon. 1879. For sale by D. Van-Nostrand.

This very exhaustive treatise is printed at Bombay, and the illustrations are taken from Indian constructions. In countries like Hindostan, where railways must always be chiefly main lines, roads are necessary, not only for local intercommunication, but as railway feeders. These are either ordinary or mountain roads. The principles of construction of the former have been pretty well ascertained; but that is not the case with the others which have been rarely made according to any fixed principles. These the author proposes to supply. The first step is to reconnoitre the site of the proposed road, the plan of which varies according as it is to traverse an approximately level, undulating or mountainous district. For this full and judicious directions are given, and then for the detailed survey. The various classes of road are next defined, their several breadths indicated, and the mode of construction described. Their maintenance and repair form the subject of a separate chapter, and the cost of roads of each class and crossing various descriptions of the country is elaborately investigated. Live loads are next examined and compared, and examples are given of the different live loads on trussed girders, which the author considers well suited for road works in a forest country; but he holds that an iron bridge should never be erected where the conditions for a masonry one are suitable, the latter being cheaper and more permanent. Copious and comprehensive as this work is, the author informs us that it is not a mere compilation, but that the opinions expressed and the designs given are the results of his personal experience. That must have been an extensive and useful one; and by putting it thus on record he has rendered an important service to the public as well as to those who may be called upon to perform similar tasks. The volume is illustrated by a score of full page cuts, showing sections or elevations of roads and bridges.

History and Mystery of Precious Stones. By William Jones, F.S.A. Richard Bentley & Son. 1880. pp. 376. For sale by D. Van Nostrand.

The vulgarization of precious stones is one of the most difficult tasks which the restless leveling spirit of the nineteenth century has set itself. If, as yet, it seems to be weaving a rope of sand, like Michael Scott's indefatigable familiar, there is no denying the fact that progress of an amazing character has been made in mineralogical synthesis. French skill has reproduced meteoric ironstone, pyroxene diopside has been got from the "Thomas" basic brick, garnets and rubies have been made in the laboratory, and the secret of crystallizing carbon is said to have been so shrewdly guessed at that the incubation of diamonds will by and by be as common an industry at Glasgow as sugar boiling. For the present, however, the romance of gems is safe from the spoiling hand of the manufacturer, if, as we desire to do, we may repose our faith on Dr. Percy's assurances, and continue to believe in the inimitable perfection of Nature's workmahship.

On the eve of Mr. McTear's revelations, however, the publication of the present work has a certain appropriateness of contrast which gives its reading an extra piquancy. All the old superstitions connected with gems are recounted, the coloring is shown which they have given to poetry and romance, to religion and to history. Leaving to the mineralogists all scientific detail, Mr. Jones has occupied himself with the archæology and the romance of gems, and has brought together and admirably classified a vast amount of scattered, often recondite, facts and fictions concerning these "flowers of the mineral world." The style is pleasant and gossipy, neat withal, and elastic enough to bear the weight of the erudition it often has to carry. The chapter devoted to the "philosophy" of gems is not the least entertaining; we are sorry, however, that it leaves undiscussed the momentous question, May a gentleman, or may he not, wear a diamond ring?

MISCELLANEOUS.

The following formula for the brilliant white enamel applied sometimes to French cards and *papier de luxe,* and which might be useful for coating models of wood, etc., is given in the *Paper Trade Circular.* For white, and for all pale and delicate shades, take twenty-four parts by weight of paraffine, add thereto 100 parts of pure kaolin (China clay), very dry, and reduced to a fine powder. Before mixing with the paraffine the kaolin must be heated to fusing point. Let the mixture cool, and it will form a homogeneous mass, which is to be reduced to powder and worked into a paste in a paint mill with warm water. The enamel is then ready for application. It can be tinted to any desired color.

In his report of the fatal accident which attended the use of dynamite in the Severn Tunnel on the 23d of September, Major Ford, inspector of explosives, expresses his opinion that the deaths were caused by the evolution of nitrous acid fumes, produced partly by firing and not properly detonating the dynamite. He considers that other noxious vapors, as carbonic oxide and acid, may have contributed to the deaths of the men, whose symptoms were very similar to those of a number of others whose cases he describes. The report is very complete and exhaustive and interesting to those interested in the use of explosives.

Ivory may be silvered by immersing it in a weak solution of chloride of silver, and letting it remain till of a deep yellow color; then take out and dip in water, after which expose to the sun's rays until black. On rubbing, the black surface will soon change to a silver.

# VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXVI.—APRIL, 1880.—VOL. XXII.

RETAINING WALLS.

By WM. CAIN, C. E.

Written for Van Nostrand's Magazine.

Prof. Weyrauch, of the Stuttgart Polytechnikum has published in the *Zeitschrift für Bankunde*, Band, 1 Heft 2, 1878, a new theory of the retaining wall, which merits notice, even by those who may regard the subject as worn threadbare, at least from a practical standpoint.

It is to be observed that all theories of retaining walls should agree if the hypotheses upon which they are founded are taken the same. Unfortunately different assumptions have been made by different authors, so that all the formulæ deduced do not agree. Thus, the direction of the earth thrust with respect to the normal to the wall, has been taken at angles varying from *o* to the angle of friction, by various writers; of course with discordant results.

It is therefore most essential in treating this subject, that hypotheses be taken in accordance with facts, and that the preliminary steps be carefully demonstrated. If, however, data is wanting, so that some indetermination necessarily exists, then it should be exposed fairly, and not set aside or replaced by some bare assumption, however confidently supported, though it may be by great names.

In endeavoring to carry out this plan in this paper, a portion of Weyrauch's new theory will be used, and his final results deduced from some simple considerations; after which the identity of these results in certain cases with those given by Rankine will be shown; and finally, the subject of the direction of the earth thrust against the wall, and the consequences resulting from various directions will be closely examined.

In this article, *we consider the earth as a homogeneous and incompressible mass, made up of little grains, possessing the resistance to sliding over each other called friction, but without cohesion.* We are well aware that the practical engineer must consider other influences, as affecting the stability of retaining walls, than the pressure of a dry homogeneous earth, devoid of cohesion; thus, the ground may become saturated with water, and this water may freeze, expanding in the act with great force; again, heavy loads may pass over the earth causing great vibrations* which cannot be included in any formulæ; still, if the engineer knows the exact influence of dry earth, not subjected to

* Trautwine states in experiments in an upper room of a strongly built dwelling, with dry sand retained by wooden walls, "that the tremor produced by passing vehicles in the streets, by the shutting of doors, and walking about the room, sufficed to gradually produce leaning in walls of considerably more than twice the mere balancing stability when quiet." See his *Engineer's Pocket-Book*, p. 333.

tremor, on walls, he should be better able to design them to withstand *all* the destructive forces to which they may be subjected than when he has no such knowledge. Let Fig. 1 represent a vertical section of a portion of the retaining wall ABCD and the earth ABF behind it, whose length, ⊥ plane of paper, is unity.

Assumption. We assume that the earth behind the wall has a tendency to slide along some *plane surface of rupture*, as Ab_1, Ab_2 . . . .

No proof is given of this assumption, but we shall find that, in certain cases,

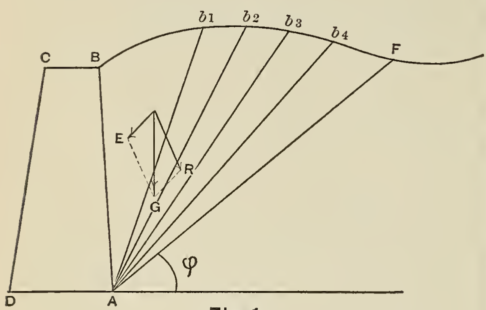


Fig. 1.

it gives identical results with theories (as Rankine's) that are not based on any principle but the known laws of friction, and hence must be correct for those cases. Afterwards, we may infer that the principle is, at least, approximately correct, for certain cases that cannot be solved by Rankine's method. The graphical method too is absolutely dependent on this assumption, so that it is important to establish it.

Coulomb's Wedge of Maximum Thrust. Let us consider the triangular prisms BAb_1, BAb_2, . . ., as regards sliding along their inclined bases Ab_1, Ab_2, ... Now if AF is at the natural slope of the earth, the tendency of the prism BAF to slide along AF would exactly be balanced by friction, as is well known. But if we consider other possible planes of rupture, lying above AF, as Ab_4, Ab_3, . . ., we see that unless the wall offers a resistance, that sliding along some one of these planes must occur.

Now it is plain, that on our hypothesis of a *plane* of rupture, that sliding *may* occur along *any one* of the planes Ab unless the wall can resist this tendency to slide.

Let us suppose the resistance of the wall to steadily increase from zero, as we consider prisms that exercise greater and greater thrusts. Now for any special value of this resistance we see that the prisms that cause a less thrust cannot slide; but those requiring a greater resistance can slide, for it is only a certain resistance that prevents them from sliding along their bases. It follows that when stability is assured, that the resistance of the wall must be sufficient to keep the prism which exercises the maximum thrust from sliding; whence follows the principle that the *true* thrust on the wall is that caused by the wedge or prism which gives a maximum thrust, the base of this prism being called the surface of rupture.

This principle is due to Coulomb, and has long served as the basis of theories of earth pressure.

The proof above has been made as plain as possible, for no less an authority than Winkler asserts that no direct, satisfactory proof of Coulomb's wedge of maximum thrust has ever been given.

Some have assumed, that if the stability of the wall against overturning is to be considered, that the wedge causing the maximum *moment* about the outer toe of the wall is the true prism of rupture. But it is plain, that if this wedge is not the one which causes the greatest thrust, that sliding must necessarily occur down the plane corresponding to the greatest thrust. So that the latter thrust is necessarily exerted against the wall, and is the only true and actual one.

Let BAb_2 represent this wedge of maximum thrust; call its weight G, the thrust against the wall E, and the pressure on the plane Ab_2, R. Now it is well known that E and R cannot make angles with the normals to the planes upon which they act greater than the angle of friction, φ of earth on earth. If the friction of the earth on the wall is greater than φ, still a thin layer of earth will go with the wall if it moves, and this layer, rubbing against the remaining earth, can only cause the friction of earth on earth. If the friction of earth on wall is less than that of earth on earth, then E cannot make an angle with the normal to the wall greater than this angle of friction of earth on wall.

If the wall is supposed perfectly smooth then E must act at right angles to its surface.

In practice, the walls are generally rough, but to complete the subject theoretically, perfectly smooth walls should be included, as special cases, in the formulæ deduced. It is to frame such *general formulæ* that we have resorted to the above hypothesis of a plane surface of rupture.

Referring to Fig. 1, we remark that the prism BAb_2 cannot slide down the plane Ab_2 until the entire frictional resistance of this plane is brought into play; whence it follows that R makes the angle φ with the normal to the plane, its direction lying nearer the vertical than the normal. If, however, the wall is subjected to a thrust from left to right in Fig. 1, due to some agency, as earth, water, etc., acting on CD from the left, and this thrust is just sufficient to cause a sliding of some prism BAb up Ab, then the direction of R on this plane will make an angle φ with the normal, though it will now lie on the other side of the normal to its first position, since the plane now resists motion upwards and not downwards as hitherto. Further, that plane is the true surface of rupture whose corresponding prism causes the *least* resistance to sliding of any conceivable prism, as is sufficiently evident.

A graphical construction will render very apparent the use of Coulomb's principle. Thus, let the right part of

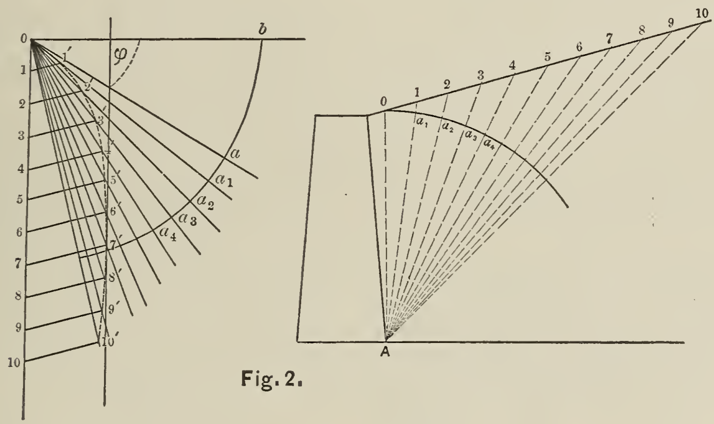


Fig. 2.

Fig. 2 represent a section of a retaining wall and the earth behind it, having the uniform top slope 0 10.

Let A0 represent a vertical plane perpendicular to the plane of the paper, one unit in length; required the pressure the earth exerts on that plane. Lay off the distances 01, 12, . . . (equal or unequal) along the top slope, draw the lines A0, A1, A2, . . .; also with A as a center and same radius, as A0, describe the arc $0a$; cutting A1 at a_1, and A2 at a_2, etc. Now, as the weights of the triangular prisms A01, A02, . . . are proportional to 01, 02, . . . (the bases of the triangles A01, A02, . . . all of them having the same altitude), lay off on the vertical line on the left the distances 01, 02, 03, . . . equal to the corresponding distances measured along the top slope of the earth. In the left figure draw $0a$ making the angle φ below the horizontal through 0. Next describe the arc ba with the radius A0, and lay off, with dividers, the chords aa_1, aa_2, aa_3, . . . equal to the chords $0a_1$, $0a_2$, $0a_3$, . . . of the right figure, and draw $0a_1$ $0a_2$, . . . in the left figure. It is evident now that the lines $0a$, $0a_1$, $0a_2$, . . . , of the left figure, make the angle φ with the normals to the planes A0, A1, A2, respectively on the right, so that they may be taken to represent the direction of the R's (Fig. 1) corresponding to those planes.

Next, let us assume the direction of the thrust E on the wall to be parallel to the top surface of earth (this subject will be considered more fully in the sequel), and draw the lines 11′, 22′, 33′, . . parallel to this top slope to intersection 1′, 2′, 3′, . . . with the lines $0a_1$, $0a_2$, $0a_3$ . . . then it follows that the lines 11′, 12′, 33′ . . . represent the thrusts on the wall E, due to the successive prisms A01, A02, A03, . . .; and by Coulomb's principle the greatest of these lines, 66′ gives the actual *active* thrust on the wall; which is thus caused by the prism A06, the plane A6 being the surface of rupture. The vertical tangent to the curve drawn through the points 1′2′3′ . . . , of course touches this curve at its greatest distance from the force line 0-10.

To get the thrust E in pounds, we have simply to multiply the length of 66′, to scale, by $\frac{1}{2}$ the perpendicular drawn from A on 0-10 (top slope) produced, and this product by the weight in pounds of a cubic unit of earth.

It is evident that the construction is more accurate the greater the number of planes of rupture assumed, especially those near the true one. To test the stability of the wall it is by no means necessary to find E in pounds. See Eddy's *Researches in Graphical Statics* further, on this graphical treatment of the subject.

In case the passive resistance of the earth to sliding up some plane is required, we lay off the angle $boa=\varphi$ above ob, and then from the point a (above b) as before, lay off arcs $aa_1=0a_1$, $aa_2=0a_2$, . . . ; the construction is then proceeded with as before. Now, however, it is the least one of the resistances, 11′, 22′, 33′, etc., that represents the greatest force the earth can withstand without sliding up the inclined plane of rupture corresponding.

In the constructions just given, we have regarded E as variable, and ascertained its maximum value—the true one —as the planes of sliding were varied.

In the method followed by Weyrauch, E *is regarded as constant* and equal to the true thrust on the wall, and *the real surface of rupture is taken to be that plane for which the normal angle of* R *is the greatest consistent with equilibrium.*

This is in perfect agreement with Coulomb's principle, for note in Fig. 2, that if the lines 11′, 22′, . . . , be extended to the vertical through 6′, so that all the thrusts E are taken equal to 66′, the true one; these lines drawn from 0 to these intersections with the vertical, representing thus the *actual* values of R for any plane, will make less angles than φ with the normals to these planes, since these directions are nearer horizontal than before. It follows that it is only along A6, the true surface of rupture, that R=06′, makes the angle φ with its normal; in other words, that the normal angle of R is a maximum.

Let us now proceed to give Weyrauch's method of finding the thrust E, in magnitude, position and direction.

To take the most general case, let Fig. 3 represent the wall AB retaining the earth whose top surface BC has any given shape.

Call G the weight of the prism of earth ABC, P and Q are its components parallel and normal to the plane AC.

R is the resistance of the plane AC, P_2 and Q_2 being its components parallel and perpendicular to AC.

E represents the resistance offered by the wall AB, P_1 and Q_1 being its components parallel and perpendicular to AC.

AB makes the angle a with the vertical, AC the angle w. We do not as yet know the angle d, that E makes with the normal to AB, but it will be eventually determined from mechanical principles.

Now G is held in equilibrium by E and R, therefore, the sum of the components ∥ AC must equal zero,

$$\therefore P-P_1-P_2=o \quad . \; . \; . \; . \; . \quad (1)$$

Also the sum of the components perpendicular to AC must be zero

$$\therefore Q+Q_1-Q_2=o \quad . \; . \; . \; . \; . \quad (2)$$

The sum of the moments of the forces E, G, and R, about any point must likewise equal zero. Let A be taken as the centre of moments, and call the lever arms of the forces E, G, and R, e, g, and r respectively; we have,

$$Gg+Ee-Rr=o \quad . \; . \; . \; . \quad (3)$$

This equation (3) was first introduced by Weyrauch to determine d, and thus avoid *assuming* some value for it, supposed to be in accordance with the truth. We shall discuss its utility further on. There is no question as to its truth. Again, we must have always,

$$\frac{P_2}{Q_2} \leqq \tan\varphi \;\therefore\; \frac{P-P_1}{Q+Q_1} \leqq \tan\varphi \quad . \; . \; . \; . \quad (4)$$

We have just seen that it is only at *the surface of rupture* that R makes the angle φ with the normal to AC, *i.e.*, that

$$P-P_1=(Q+Q_1)\tan\varphi \quad . \quad . \quad . \quad . \quad (5)$$

The position of this plane of rupture is thus determined by making $\frac{P-P_1}{Q+Q_1}$ a *maximum*, consistently with equilibrium.

In order to find this position of AC, we place, as usual, the first differential coefficient equal to zero.

$$\therefore \frac{d\left(\frac{P-P_1}{Q+Q_1}\right)}{dw}=0 \quad . \quad . \quad . \quad . \quad . \quad (6)$$

It must be remembered that E is taken as constant and equal to the true earth pressure on the wall, whilst G and R and w, as well as $AC=k$ vary.

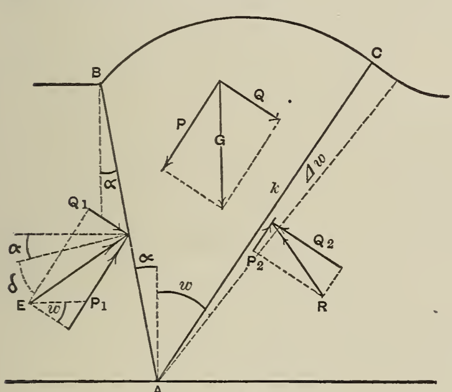


Fig. 3.

From Fig. 3 we readily find,

$$P=G\cos w,\ Q=G\sin w,\quad P_1=E\sin(w+a+d)$$
$$Q_1=E\cos(w+a+d)$$

For *the surface of rupture*, we have from (5),

$$G\cos w-E\sin(w+a+d)$$
$$=[G\sin w+E\cos(w+a+d)]\tan\varphi$$

whence,

$$E=\frac{\cos w-\sin w\tan\varphi}{\sin(w+a+d)+\cos(w+a+d)\tan\varphi}G$$

$$\therefore E=\frac{\cos(\varphi+w)}{\sin(\varphi+w+a+d)}G \quad . \quad . \quad . \quad . \quad (7)$$

This equation, it must be borne in mind, is true only for the surface of rupture. We have now from (6)

$$\frac{d}{dw}\left(\frac{G\cos w-E\sin(w+a+d)}{G\sin w+E\cos(w+a+d)}\right)=o$$

Performing the differentiation, remembering that G and w are the only variables, and putting the numerator equal to zero, since the denominator is finite, we have after simple reductions

$$-G^2+2GE\sin(a+d)$$
$$+E\cos(a+d)\frac{dG}{dw}-E^2=o$$

Calling γ the weight of a cubic unit of earth, the length AC being called k, we have nearly,

$$\varDelta G=\tfrac{1}{2}k\varDelta w.k\gamma$$

and exactly at the limit,

$$lim\frac{\varDelta G}{\varDelta w}=\frac{dG}{dw}=\tfrac{1}{2}k^2\gamma$$

Substituting in the preceding eq., we have,

$$\frac{G}{E}-2\sin(a+d)-\frac{k^2\gamma}{2G}\cos(a+d)+\frac{E}{G}=o$$
$$. \quad . \quad . \quad . \quad (8)$$

Substituting the values of $\frac{G}{E}$ and $\frac{E}{G}$ from (7) we find,

$$G=\frac{k^2\gamma}{2}\ \frac{\cos(a+d)\cos(\varphi+w)\sin(\varphi+w+a+d)}{D}$$

where,

$$D=\sin^2(\varphi+w+a+d)+\cos^2(\varphi+w)$$
$$-2\sin(a+d)\sin(\varphi+w+a+d)\cos(\varphi+w)$$

By successive trigonometrical reductions D becomes $\cos^2(a+d)$, whence we have for the weight of the *prism of rupture*,

$$G=\frac{\cos(\varphi+w)\sin(\varphi+w+a+d)}{\cos(a+d)}\cdot\frac{k^2\gamma}{2}$$
$$. \quad . \quad . \quad (9)$$

Substituting the value of $\sin(\varphi+w+a+d)$ drawn from (9) in eq. (7), we have,

$$E=\frac{\cos^2(\varphi+w)}{\cos(a+d)}\cdot\frac{k^2\gamma}{2} \quad . \quad . \quad . \quad . \quad (10)$$

We have also, since the sum of the horizontal components of E, G and R must be zero,

$$E\cos(a+d)=R\cos(w+\varphi)$$

whence,

$$R=\cos(\varphi+w)\frac{k^2\gamma}{2} \quad . \quad . \quad . \quad . \quad (11)$$

These equations 9, 10 and 11, still include w and d, as yet undetermined.

By the aid of Fig. 4, the values of G, E and R may be represented graphically. Thus, let AD be the natural slope, AC the surface of rupture, and CH a perpendicular let fall from C on AD. The angle ACH is thus equal to $w+\varphi$. Now draw CI making the angle HCI equal to $\alpha+d$ the angle of E with the horizontal, and draw AN⊥CI, then it follows that *the area of the triangle* ACI *is equal to the area* ABC *of the base of the prism of rupture.* This is made evident by writing (9) in the following form, remembering that $AC=k$:

$$G=\frac{\gamma}{2}.$$

$$k\cos(\varphi+w).k\sin(\varphi+w+\alpha+d).\sec(\alpha+d)$$

$$=\frac{\gamma}{2}\,CH.AN.\frac{CI}{CH}=\gamma.\frac{AN.CI}{2}.$$

Now lay off IL=IC and AM=AC, *then the product of* γ *by the area of the triangles,* CIL *and* ACM, *gives the pressures* E *and* R *respectively.*

Write 10 and 11 as follows:

$$E=\frac{\gamma}{2}.k\cos(\varphi+w).k\cos(\varphi+w)\sec(\alpha+d)$$

$$=\frac{\gamma}{2}CH.CI=\gamma.\frac{CH.IL}{2}.$$

$$R=k\cos(\varphi+w)\frac{k}{2}\gamma=CH\frac{k}{2}\gamma$$

$$=\gamma.\frac{CH.AM}{2}.$$

We have thus shown that

$$G=\gamma.\Delta ACI$$
$$E=\gamma.\Delta LCI$$
$$R=\gamma.\Delta ACM$$

the symbol Δ here denoting "area of triangle."

Rebhahn, in 1871, found the first two

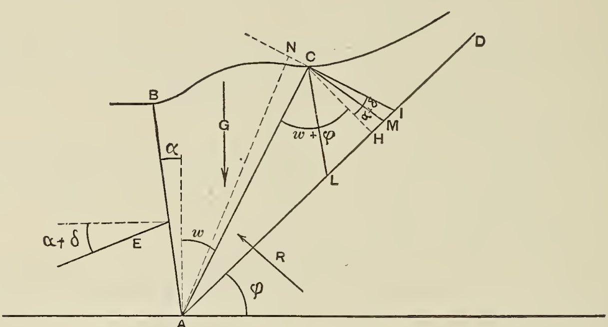


Fig. 4.

of the above relations, assuming, however, that $d=o$ or $d=\varphi$. The third relation is new and due to Weyrauch.

We can state these relations also in the form of a proportion,

$$G:E:R::AI:IC:AC \quad .\ .\ .\ . \quad (12)$$

Or G, E and R are as the sides of the triangle ACI.

The above relations have been established irrespective of any particular values of d, and irrespective of the character of the curve BC of the surface of the ground.

We cannot proceed further with this general solution, but must now consider *the earth surface as sloping at some angle,* ε *to the horizontal.*

From Fig. 5, we note the following relations of the angles:

$$BAC=\alpha+w$$
$$ACB=90-(w+\varepsilon)$$
$$ABC=90-(\alpha-\varepsilon)$$
$$CAD=90-(w+\varphi)$$
$$ACI=w+\varphi+\alpha+d$$
$$ADC=\varphi-\varepsilon$$

Now since, $\Delta ABC=\Delta ACI$,

$$AB.AC\sin BAC=AI.AC\sin CAI.$$

$$\therefore \frac{AB}{AC}.\sin BAC=\frac{AI}{AC}\sin CAI$$

whence,

$$\frac{\sin ACB.\sin BAC}{\sin ABC}=\frac{\sin ACI.\sin CAI}{\sin AIC}$$

$$\therefore \sin(\alpha+w)\cos(\varepsilon+w)\cos(\alpha+d)=$$
$$\sin(\varphi+w+\alpha+d)\cos(\varphi+w)\cos(\alpha-\varepsilon) \quad .\ .\ .\ .\ .\ (13)$$

Draw BN⊥BD.

$$\text{Now } \Delta ABD=2\Delta AIC+\Delta IDC$$

$$\therefore AD.BN=2AI.CH+ID.CH.$$

Now drawing BO || CI making angle NBO$=\alpha+d$,

$$\frac{BN}{CH}=\frac{BO}{CI}=\frac{OD}{ID};$$

whence dividing the previous equation by CH, and reducing by these relations, we have,

$$AD.OD=ID(AI+AD).$$

$$\therefore\ AD(AD-AO)=(AD-AI)(AI+AD)$$

$$\therefore\ AO.AD=\overline{AI}^2 \quad . \quad . \quad . \quad . \quad (14)$$

Therefore AI is a mean proportional between AO and AD. So that to find the surface of rupture, when d is known, we draw BO, making the angle $\alpha+d$ with the normal to the natural slope; then we lay off AI$=\sqrt{AO.AD}$, and from I draw the line IC || OB to C; whence AC is the surface of rupture, and the angle w is determined. On multiplying γ by the area of the triangle ICL or by substituting the values of w and d in eq. 10, we have the value of E.

AI may be determined graphically by describing a semi-circle on AD, and drawing a line ⊥ AD at O to the curve. This line is, of course, a mean proportional between AO and AD, and is therefore equal to the required line AI.

We shall now proceed to frame a formula for E in which the angle w does not appear. We have

$$E=\gamma.\Delta CIL=\tfrac{1}{2}\gamma.\overline{IC}^2\cos(\alpha+d)$$

$$\frac{CI}{BO}=\frac{AD-AI}{AD-AO}$$

$$=\frac{AD-\sqrt{AD.AO}}{AD-AO}=\frac{1-\sqrt{\dfrac{AO}{AD}}}{1-\dfrac{AO}{AD}}$$

Placing $n=\sqrt{\dfrac{AO}{AD}}$, we have

$$CI=\frac{1-n}{1-n^2}\,BO=\frac{BO}{1+n}$$

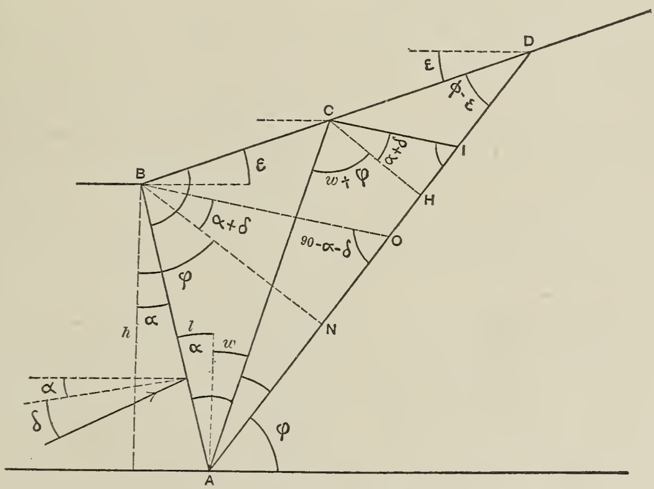


Fig. 5.

In Fig. 5, angle ABO$=\varphi-\alpha+\alpha+d$ $=\varphi+d$, whence,

$$\frac{AO}{AB}=\frac{\sin(\varphi+d)}{\cos(\alpha+d)},\quad \frac{AB}{AD}=\frac{\sin(\varphi-\varepsilon)}{\cos(\alpha-\varepsilon)}$$

Multiplying these two equations together, and extracting the square root, we find,

$$n=\sqrt{\frac{\sin(\varphi+d)\sin(\varphi-\varepsilon)}{\cos(\alpha+d)\cos(\alpha-\varepsilon)}}\ldots\ldots(15)$$

Put AB$=l$, then since

BAO$=90-(w+\varphi)+\alpha+w=90-(\varphi-d)$

$$BO=\frac{\cos(\varphi-\alpha)}{\cos(\alpha+d)}\,l$$

Substituting these values of BO and n in that for CI, and this in value for E,

$$E=\left(\frac{\cos(\varphi-\alpha)}{n+1}\right)^2\frac{l^2\gamma}{2\cos(\alpha+d)}\quad . \quad . \quad . \quad . \quad (16)$$

Or calling the height of B above A, $h=l\cos\alpha$,

$$E=\left(\frac{\cos(\varphi-\alpha)}{(n+1)\cos\alpha}\right)^2\frac{h^2\gamma}{2\cos(\alpha+d)}\quad\ldots\ldots(17)$$

It is to be observed that when $\varepsilon=\varphi$, $n=o$, which simplifies the formulæ very much for this case. *In the case of liquids*, we have,

$\varphi=o$, $\varepsilon=o$, $d=o$, $n=o$, and $E=\frac{1}{2}h^2\gamma\sec.\alpha$,

a well known formula.

We are now going to determine the angle d for earth pressure. Prof. Weyrauch does this by the use of eq. (3), which we have not used as yet. The following is a quotation from his article before referred to.

"In order to express e and r in eq. (3), the points of application of E and R must be known. The angles d and w can be determined the one from the other by means of (13). Now since d is independent of the depth, this is also true of w; therefore, regarding h as variable, from (16) and (11), we can write,

$$E=Cl^2 \qquad R=C_1k^2$$
$$dE=2Cldl, \quad dR=2C_1kdk;$$

and we obtain the distances x, z, of the points of application from A, from the eqs.

$$E(l-x)=2C\int_o^l l^2dl \ \therefore\ x=\frac{l}{3}$$

$$R(k-z)=2C_1\int_o^k k^2dk \ \therefore\ z=\frac{k}{3}$$

whence,

$$e=\frac{l}{3}\cos d,\ r=\frac{k}{3}\cos\varphi$$

$$g=\frac{k}{3}\sin w-\frac{l}{3}\sin\alpha\text{"}$$

By substituting these values, &c., Prof. Weyrauch deduces a complicated equation, which with the aid of (13) suffices to determine d.

The reductions required, even for the simplest cases, $\varepsilon=o$ and $\varepsilon=\varphi$ (it was not attempted for any other values of ε), are long and tedious in the extreme; but fortunately they can all be avoided by some simple considerations, for which, as well as for the remainder of this article, the writer must alone be held responsible.

But first, let us inquire more particularly into the method used above for finding e and r. Refer to Fig. 6, where AC is the plane of rupture, 13 || 24 || AC, and ab || a_1b_1 || AB. Now by our theory the thrust on the part $\overline{B1}$ of the wall is $C.\overline{B1}^2$, that on B2, is $C,\overline{B2}^2$, so that the actual thrust on the part 12 is

$$C(\overline{B2}^2-\overline{B1}^2)=\varDelta E,$$

whence the value of dE, &c., is correctly found as above; so that *when the earth surface is plane, the thrust* E *always acts on* AB *at* $\frac{1}{3}$ AB *above* A.

The same method applies in finding the position of R, provided the *actual* thrusts on the the planes Ca and Ca_1 are due to the prisms Cab and Ca_1b_1 respectively. To prove that this is so, we

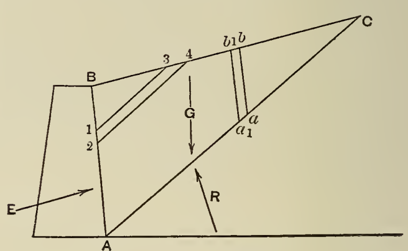


Fig. 6.

observe that the thrust on any plane ab parallel to AB, must have a direction parallel to E, since the same considerations determine its direction for plane ab as for plane AB. Therefore the direction of the thrust on Ca will be parallel to R, thus making the angle φ with the normal to AC; so that the prism Cab will be just on the point of sliding. Now, as this is as it should be, since AC is the plane of rupture, it follows that the *actual* thrust on Ca is given by the prism Cab; so that the thrust on the part aa_1 is the difference of the thrusts due to the two prisms Cab and Ca_1b_1, and of course acts parallel to R. It easily follows that R is applied at a point on AC, at a distance $\frac{1}{3}$ AC from A.

Now consider Fig. 7, in which G, the weight of the prism of rupture BCA, is decomposed by a vertical plane AD into two weights, W=weight of BAD and W′=weight of DAC. Since W and W′ act at the centers of gravity of the triangles ABD and DAC, their directions must intersect AB and AC respectively at the points of application of E and R, *i.e.*, one third of the distances AB and AC from A along the planes AB and AC respectively. *It follows that* F, *the resultant of* W′ *and* R *must be parallel to the upper surface* BC, *and act at* $\frac{1}{3}$ AD *above* A.

On combining F with W we, of course, find E. Now since W is constant for any assumed position of BA, we see, that E is a maximum when F is a maximum. But F is a maximum when DAC is the prism of rupture for the plane AD, according to Coulomb's principle; therefore the plane of rupture AC for plane AD is also the plane of rupture for the plane or wall AB; *hence a simple method of procedure for finding* E, *when the top surface slopes uniformly, is to find the thrust on a vertical plane* AD *through* A, *which thrust acts parallel to the top slope and at* $\frac{1}{3}$ AD *above* A, *and afterwards combine this thrust with the weight of the prism of earth* ABD *which gives the resultant* E *required.*

It is needless then to encumber our formulæ for this case by inserting the angle α, since E can be so quickly found when F is known.

It follows from what we have said, that when F acts parallel to the top slope, the surface of rupture, AC, is independent of the inclination of AB. The case is different when we have to assume some direction to E, from physical considerations, as we shall see further on.

The fact that the thrust on a vertical plane, as AD, is parallel to the top surface is proved by Rankine in the following manner, in the case of a mass of earth extended laterally and downwards indefinitely. In Fig. 7 consider the element e, bounded by planes vertical and planes parallel to the top slope. *If the mass is exposed to no external force but its own weight*, the only pressure which any portion of a plane $mn \parallel$ DC can have to sustain, is the weight of the material directly above it, so that the pressure on the plane mn is everywhere uniform and vertical. The pressures on the upper and lower surfaces of the particle e, are thus vertical and their difference is equal, and opposite to, and balanced by, the weight of the particle. It follows that the pressures on the opposite vertical faces of the particle must balance each other independently, which can only happen when they act parallel to the top surface, in which case only they are directly opposed. It follows too, that the intensity of pressure at the same depth is everywhere the same, as we have previously seen to be true.

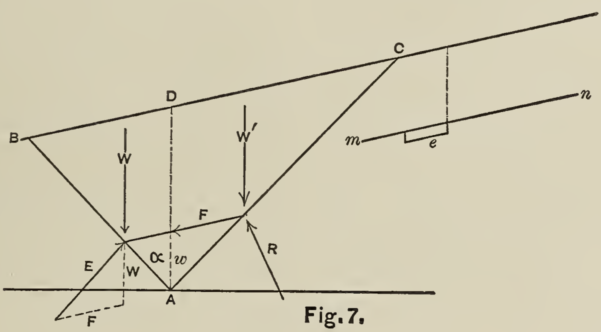


Fig. 7.

By different methods of reasoning we have thus reached the same conclusions, which are all true therefore, unless the wall AB introduces some modifying influences—some "external force" not considered above.

Since we have proved, that unless the wall causes modifying influences, that the thrust on a vertical plane is parallel to the top slope, we have from eq. (16), when $a=o, d=\varepsilon$ and $l=x=$AD (of Fig. 7), this earth thrust on AD (Fig. 7),

$$E=\left(\frac{\cos\varphi}{n+1}\right)^2\frac{x^2\gamma}{2\cos\varepsilon}.$$

Also,

$$n=\sqrt{\frac{\sin(\varphi+\varepsilon)\sin(\varphi-\varepsilon)}{\cos^2\varepsilon}}$$

$$=\frac{1}{\cos\varepsilon}\sqrt{\sin^2\varphi\cos^2\varepsilon-\cos^2\varphi\sin^2\varepsilon}$$

$$\therefore\ n=\frac{\sqrt{\cos^2\varepsilon-\cos^2\varphi}}{\cos\varepsilon}$$

and,

$$E=\frac{\cos^2\varphi}{(\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi})^2}\ \frac{x^2\gamma}{2}\cos\varepsilon$$

Now since,

$$\cos^2\varphi=(\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi})\overline{(\cos\varepsilon-\sqrt{\cos^2\varepsilon-\cos^2\varphi})}$$

we have, on dividing the numerator and denominator of E by

$$(\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi}),$$

$$E=\frac{\gamma x^2}{2}\cos\varepsilon\frac{\cos\varepsilon-\sqrt{\cos^2\varepsilon-\cos^2\varphi}}{\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi}} \quad . \ . \ . \ . \ (18)$$

which is Rankine's well known formula for earth pressure.

Now since Rankine's formula was framed without the use of any assumption, as that of a *plane* of rupture, and is accepted as correct, it must follow that the supposition that the surface of rupture is a plane, when the top surface is a uniform slope and the wall does not produce any external force, must be correct.

We are therefore safe in saying that it is, at least approximately correct, in other cases; so that the graphical treatment founded on this supposition may be relied on as giving good results. Rankine has given in his *Engineering* a very pretty graphical construction of the last fraction in eq. (18), that saves labor in computing.

When the top surface is level, $\varepsilon=o$, and we have,

$$E=\frac{\gamma x^2}{2}\frac{1-\sin\varphi}{1+\sin\varphi}=\frac{\gamma x^2}{2}\tan^2\left(45°-\frac{\varphi}{2}\right) \quad . \ . \ . \ . \ (19)$$

When the surface slopes at the angle of repose, $\varepsilon=\varphi$.

$$E=\frac{\gamma x^2}{2}\cos\varphi \quad . \ . \ . \ . \ (20)$$

The pressure E in all cases acts parallel to the top slope and at a height $\frac{1}{3}x$ above A.

On combining these values of E with the weight W of the prism ABD (Fig. 7) we find the values for the pressure on the wall AB given by Weyrauch for the two cases $\varepsilon=o$ and $\varepsilon=\varphi$. Similarily his values for $\tan(a+d)$ are readily found. There seems to be no advantage to be derived from deducing these values, since the weight of the wall and of the prism ADB can be taken together as acting at their common center of gravity, in testing the wall, either as to its stability against overturning, or as regards sliding on its base. Besides, it is simpler to have one formula (18) that solves every case, and that can moreover be easily remembered.

We have hitherto supposed that the wall was immovable, so that the pressure upon it would be the same as upon a section AB in an indefinitely extended mass of earth; besides it has been tacitly assumed that the friction between the wall and the earth was at least equal to that between earth and earth.

The case is different if the wall is just on the point of overturning, or sliding on its base, for now the friction between the earth and wall causes E to make an angle φ with the normal to the wall. *Now if the surface of rupture* AC *for this case is supposed to be plane*, as before, then R cannot act at $\frac{1}{3}$ AC from A, if E makes an angle with the normal to AB greater than results from previous considerations; hence, *thrusts on planes ab* (Fig. 6) *are no longer parallel to* E, otherwise we should undoubtedly deduce, as previously shown, that R acts at $\frac{1}{3}$ AC from A; whereas it is plain that it must act above its present position. This is as we should expect, for it is only at the wall AB that the greatest movement and friction occurs to alter the *usual* direction of the thrust in a mass of earth of indefinite extent, which we have shown to be parallel to the top surface of the earth, when taken on a vertical plane, perpendicular to the plane of the section.

Similarly if the angle of friction between the wall and earth is less than d, as determined above, then E must be regarded as making this angle of friction with the normal to the wall.

It is plain now that R acts nearer A than $\frac{1}{3}$ AC. If the wall is regarded as *perfectly smooth*, so that E is nearly horizontal, then R acts nearer A than on any other supposition. In all these cases, as we go from the wall, the direction of the thrust on planes such as *ab* (Fig. 6) is constantly changing until the usual direction of this thrust is attained.

It is evident that eq. (3) can be of no use in these cases, since r cannot be determined. *However, having assumed d in accordance with the facts of the case,* *the thrust* E *at once follows from eqs.* (16) *and* (17). The thrust E of course acts on AB at $\frac{1}{3}$ AB from A.

It has been the fashion with many recent writers on this subject to *assume* $d=\varphi$ in every case. Now it is evident that for values of ε less than φ the full friction between the earth and wall cannot be exerted except when motion is about to begin. Thus, in experiments with models, this supposition $d=\varphi$ agrees (as far as I know) with actual results better than any other, when coupled with a *rational* theory. But if the wall has a large excess of stability any motion forward will be slight. In fact, if the wall is given such a shape that the final resultant on its base passes through its center, then there can be no motion forward at all, and hence no friction at the wall over that found before. If, however, this resultant passes near the outer edge there will be slight forward motion, even with a firm rock foundation, and considerable forward rotation if the foundation is not practically incompressible. Again, it may be that the settling of the earth, after it is deposited, may cause considerable friction at the back of the wall, which, however, may be gradually destroyed by vibrations, rains, etc.

Admitting, then, that this settlement of the wall and earth cause a certain amount of indetermination as regards the direction of the thrust E, it is certainly well in a practical point of view to take the most unfavorable case in *designing a wall; in other words, use eq.* (18), *regarding* E *as acting parallel to the top slope, since this gives a greater thrust than when* E *is given a direction nearer the vertical*, as we see plainly from Fig. 2. Weyrauch urges the following objections to taking $d=\varphi$ in all cases: take a tunnel arch, and if we suppose the pressure, as we go up from either side, to make always the angle φ with the normal, we shall have at the crown two differently directed pressures, both making an angle φ with the vertical normal, but on opposite sides. Or take a horizontal wall with level topped earth resting on it. The pressure, of course, should be vertical. These objections are sound if no motion occurs, but if the tunnel arch or horizontal wall are just on the point of moving then, as in the case of the retaining wall, just at the limit of stability, there is friction exerted in a certain direction so that the thrust can have but *one* direction making the angle φ with the normal; in fact, Weyrauch admits as much himself, where *sliding* of the wall on its base occurs; and it is difficult to see how it can be otherwise in the case of a wall just at the limit of stability. It may be observed here that in experiments on models the earth should not be confined in a box, for as the wall gives there is friction exerted between the sides of the box and the prism of rupture as it moves downwards. It seems best to adopt Trautwine's method of having the earth unconfined, the wall tapering at its ends with the side slopes of the earth, its thickness likewise diminishing to nothing as the bottom of the slope is reached. The wall should be as long as convenient in order to eliminate the error due to the unknown thrusts from the side slopes as much as possible.

In cases where the earth behind a retaining wall is loaded uniformly, we find the additional height, x_0 of earth required to have the same weight, and estimate the earth thrust on a vertical plane, for the depth x_0, as well as for the depth, $H=x+x_0$, x being the original depth of earth. Their difference gives the earth thrust on the original plane whose height is x.

The point of application of this thrust (which may be represented graphically by a trapezoid) is at a height above the lowest point,

$$y=\frac{1}{3}\frac{H^3-x_0^3}{H^2-x_0^2}.$$

Referring once more to eq. 17, we see that for the theoretical case of a vertical wall, *perfectly smooth*, the surface earth sloping at the angle of repose, for which $d=o$, $\varepsilon=\varphi$ and $\alpha=o$, that $n=o$, and,

$$E=\frac{h^2\gamma}{2}\cos^2\varphi$$

This value is the horizontal component of the value of E given by eq. (20), where the wall is supposed to be capable of affording the friction with the earth, whose coefficient is *tan* φ.

This value is found likewise directly from eq. (7) on substituting for G its value for this case,

$$G=\frac{\gamma h^2}{2}\,\frac{1}{\cot w-\tan\varphi}=\frac{\sin w\cos\varphi}{\cos(w+\varphi)}\,\frac{\gamma h^2}{2}$$

We have now from (7), on making $a=o$, $d=o$

$$E=\frac{\cos(\varphi+w)}{\sin(\varphi+w)}\frac{\sin w\cos\varphi}{\cos(w+\varphi)}\frac{\gamma h^2}{2}$$

$$=\frac{\gamma h^2}{2}\frac{1}{1+\tan\varphi\cot w}$$

Now by Coulomb's principle this value of E is to be a maximum. The only variable in the right member being *cot w*, which is smaller as w is greater, we evidently make E a max. by giving w its greatest value $(90-\varphi)$, in which case the surface of rupture coincides with the line of natural slope through the foot of the wall—its *limiting position.* E now becomes

$$\frac{\gamma h^2}{2}\frac{1}{1+\tan^2\varphi}=\frac{\gamma h^2}{2}\cos^2\varphi,$$

the value before found. It will be observed that this result is reached without the aid of the calculus.

The same style of demonstration applies in deducing eq. (20) without the aid of the calculus.

We have now in eq. (7), $a=o$, $d=\varphi$, and the value of G as given above,

$$\therefore\ E=\frac{\sin w\cos\varphi}{\sin(2\varphi+w)}\frac{\gamma h^2}{2}=$$

$$\frac{\cos\varphi}{\sin 2\varphi\cot w+\cos 2\varphi}\frac{\gamma h^2}{2}$$

which is a max., as before, for $w=90-\varphi$. Whence, at the limit,

$$E=\frac{\gamma h^2}{2}\cos\varphi$$

The surface of rupture in this case coincides with the line of natural slope. Eq. (7) in this case assumes the form, $o\times\infty$, since G becomes infinite for an indefinitely sloping surface; but on reducing to the form above, we easily see the limit that E approaches but cannot exceed, which is its true value.

By reference to eq. (19), it is seen that for the case of a *level topped bank* that, $w=45°-\frac{\varphi}{2}$, or $2w=90-\varphi$, since this value alone will give (19). *For level topped earth then, the line of rupture bisects the angle between the vertical and the line of natural slope.*

In the case of a liquid, $\varphi=o$, whence w makes an angle of 45° with the vertical.

It is not proposed in this paper to frame equations by which to compute the thickness of retaining walls, since this part of the subject has been fully discussed by Rankine and others. Suffice it to say that on combining the earth thrust on a vertical plane through the inner foot of the wall with the weight of earth and wall in front of it acting at their common center of gravity, that we find, by a graphical construction, the point where the resultant strikes the base of the retaining wall and its inclination to the normal to that base. If the latter is less than the angle of friction between this base and the foundation, then the wall will *slide* outwards, and either the base must be inclined more to the horizontal, or this friction must be increased in some way as by imbedding stones in the foundation surface, or if it is of timber, by allowing beams to project above its surface, etc.

It will be found that for walls having a considerable batter, or with counterforts, that sliding is more to be feared than overturning when the foundation is of wet clay or timber, the co-efficients of friction for these cases ranging as low as .33 to .4, whilst for rock it averages two-thirds.

To insure a proper excess of stability against overturning, Rankine says that English and French engineers allow the resultant to approach no nearer the outer edge than from $\frac{1}{8}$ to $\frac{1}{5}$ of the width of base.

However this may be, it is certain that if we regard the wall as made up of blocks resting on each other, and extending the entire width of the wall, that if the resultant on any block falls without the middle third of the joint, that the joints will open along their inner edges, thus allowing the infiltration of water. Stability is, of course, assured against overturning when the resultant strikes anywhere within the base, provided crushing of the outer toe is not to be feared; and this holds generally when the resultant is limited to an extreme approach to this toe of $\frac{1}{8}$ to $\frac{1}{5}$, the diameter of base; but it seems to me that this limit introduces too small "a factor of safety," considering that rains may saturate the ground, and not only increase the specific gravity of the mass pressing against the wall but lessen its friction, not to speak of the effects of this water when freezing and expanding.

To use every precaution, gravel or dry rubble should be put next the wall for a foot in thickness, say, and weeping holes and drains must be provided along the foot of the wall to pass off the water. In dock walls the earth is often saturated with water unless a puddle wall is built next the retaining wall.

Again, in all cases where loads pass over the earth, accompanied by jars, the pressure against the wall is increased, so that when all the influences are considered that we have enumerated, it would seem that Rankine's factor of safety is certainly the minimum one.

It should be remembered that whenever the resultant lies near the outer toe that there will be greater compression caused there than at the inner toe, so that the wall will *lean* slightly forwards, thus moving the center of gravity of the wall slightly forwards. This slight forward movement, though, causes friction between the earth and wall, which may help to counteract its bad effects.

Often the relative specific gravity of the masonry to the earth is taken too high.

It would seem *safe* to assume the weight per cubic foot of settled earth to vary from 120 to 130 lbs., of brickwork 110 lbs., of sandstone masonry 130 lbs., and of granite masonry 142 lbs.—the walls consisting of one-half ashlar and one-half rubble backing. The value of φ may be taken at 34°. We have hitherto considered the case where the wall A B makes an angle a to left of the vertical. When the wall leans to the right of the vertical, or backwards, the case is as given by Rankine in his *Civil Engineering*, unless we have to assume some value of d (when wall is at or near the limit of stability) not in agreement with Rankine's determination, in which case a becomes negative in formulae (15) and (16), and the value of E is found from them, after substituting the assumed value of d.

A strict solution of the case where *the earth surface is of irregular shape* seems impossible; for now it cannot be proved that the direction of the earth thrust at different depths is the same, so that this direction remains indeterminate (unless the wall is at the limit of stability, when it will be inclined at the angle φ to the normal to the *rough* wall); besides, since the pressure cannot be shown to increase uniformly as we go downwards, the position of the resultant earth thrust is indeterminate. We can say generally that this position for surcharged revetments is somewhere between $\frac{1}{3}\,h$ and $\frac{1}{2}\,h$ above the base of the wall. It can never reach the latter value, which corresponds to a uniformly distributed thrust, and it most likely never exceeds $\frac{4}{10}\,h$; still any attempt to locate this resultant exactly is only guess work. Lastly, the surface of rupture is most probably no longer a plane, though we have to assume that it is.

An approximate solution of this case can best be made by a graphical analysis similar to that given in Fig. 2. The only difference being that the triangles forming the bases of the successive prisms of rupture must each be reduced to equivalent triangles having the same altitude, so that their bases can then be laid off on the load line representing the forces G. This is easily done by the usual geometrical method of forming equivalent triangles having the same base and altitude. Next, an approximation for a stable wall the direction of the thrust may be assumed as a rough mean of the inclinations of the upper surface of the probable prism of rupture, and this prism then determined by construction. It is plain that if the earth thrust is taken perpendicular to the wall, that it will be a maximum, and therefore the assumption is a safe one.

In conclusion, the writer is aware that in opening the discussion of earth thrust again, it would seem that some apology was needed, except that the aim has been rather to reconcile conflicting theories where possible, and show their common points than to advance any perfectly novel theory of his own. Irrational theories are still being presented, and it is necessary to guard against them by bearing well in mind what has been established as true and what as false, and more especially by a consideration of the subject in its most comprehensive aspect.

COMPOUND ARMOR

From "Iron."

The battle of Guns *versus* armor has been fought—and well fought, too—for many years past. At one time it has been the guns that have had the best of it, whilst at another the plates have baffled the guns. No sooner has this latter condition obtained than the guns have been increased in size and power, until at last they would seem to have been left masters of the situation. This being the case, another effort to turn the tables upon the guns has been made, this time not by increasing the thickness of the iron plates, which had already about reached the limits of safety as regards the ship, nor by making them of steel, which is not adapted to resist every kind of artillery fire, but by effecting a compromise, and using both these metals in conjunction. The precise value of steel, as a material for armor plates, was established by the artillery experiments which were carried out in the autumn of 1876 at Spezzia. There both wrought iron and steel plates were tried by both light and heavy artillery. The results showed that whilst 10-inch projectiles penetrated from 10 to 13 inches into the solid iron plates, the steel plates, though not penetrated were so starred and split by the racking to which they had been subjected that they threatened to fall to pieces. But whilst the steel plates were unable to withstand a continuous fire from even comparatively light ordnance, they nevertheless resisted the punching energy of the 100-ton gun, though shivering under blows which easily penetrated the iron armor. The inference drawn from these and other circumstances was that steel was well calculated to enable a vessel to bear a single blow of a projectile from a gun of superior power to its armor; while, on the other hand, such plating must be expected to crumble under the continuous fire of guns which could not easily injure wrought-iron armor of the same thickness.

The question arising upon this was how the special qualities both of the iron and the steel might best be turned to advantage in keeping out the projectiles. In other words, the manufacturers of armor-plates had to discover the means of producing plates which should be proof against both the punching and the racking effects of artillery fire. For the successful solution of this problem the country is indebted to our two great armor-plate makers, Messrs. John Brown & Co., of Sheffield, under their chairman's—Mr. Ellis—patent, and Messrs. Cammell & Co., also of Sheffield, under Mr. Alexander Wilson's patent. The way in which they solved the question was to effect a perfect union of the two metals and to produce a compound plate, that is, a plate having a steel face and an iron backing. Here the steel does its work in preventing penetration by causing the shot to break up on impact, whilst the iron performs its part in preventing the destruction of the steel by reason of its greater tenacity and ductility. We need hardly say that the two metals had previously been successfully welded together for use in railway practice, but the conditions in artillery practice were so widely different that, plates simply welded together were found to separate very soon under fire in the early experiments with compound plates. The method by which these plates are now produced by the firms we have mentioned consists in pouring the liquid steel upon the heated iron plate, the details of the process, however, differing in each case. In this process the temperature of the molten steel being in excess of the welding heat of the iron, the surface of the heated iron plate becomes partially fused by the liquid steel, and thus a complete union or weld between the two metals is obtained. In this case the weld is not confined to a simple line marking the difference between the steel and the iron, as in ordinary welds, but a third metal or semi-steel is formed between the two, varying in thickness from $\frac{1}{8}$ inch to 3-16 inch, by the carbon of the steel running into the iron. Through the formation of this zone of anomalous steel the two metals are joined together inseparably; or, in other words, the steel has gradually run into the fibrous iron and the iron into the steel. Experiments have been made to ascertain the relative strength of the weld thus produced, and on every occasion the iron only has been torn asunder, while the weld itself remained undisturbed.

The experience thus gained led the constructive department of the Admiralty to direct that the turrets of the *Inflexible* should be plated with compound armor, which, as a matter of fact, is now in course of being done. The testing of the plates for this vessel, in conjunction with the results of the previous experiments, so satisfied the Admiralty as to the superiority of steel-faced plates over every other description of armor, that they have finally adopted it as a means of defence for our future ships of war.

THE ABSOLUTE ZERO OF TEMPERATURE.

By J. F. KLEIN, D. E., Instructor in Dynamical Engineering, Sheffield Scientific School.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

In the February number of this Magazine Professor Wood has called attention to an erroneous article on the above subject in the November issue, taken from the *Revue Industrielle.* We wish Professor Wood had gone further, and not only pointed out that the formula for the volume of a gas which was then deduced did not accord with experiment, but had also pointed out the two very common errors on which the formula was based. The first of these two errors consists in supposing that the absolute zero of temperature depended upon and could only be determined from the coefficient of dilation of a perfect gas, and that since there are no perfect gases there must be as many absolute zeros as there are gases or coefficients of dilation.

The second error consists in misunderstanding what is meant by the coefficient of dilation.

We believe that the first of these errors can be best met, and *absolute* temperature best explained, by stating the meaning and origin of this term without attempting to give its physical interpretation, for we thus avoid all hypothesis as to the nature of heat and all speculations as to what possibly might take place if the absolute zero could be reached.

The absolute scale of temperature is due to W. Thomson, who pointed out that "any system of thermometry, founded either on equal additions of heat, or equal expansions, or equal augmentations of pressure, must depend upon the particular thermometric substance chosen, since the specific heats, the expansions and the elasticities of substances vary, and, so far as we know, not proportionally with absolute rigor for any two substances. Even the air thermometer does not afford a *perfect standard*, unless the precise constitution and physical state of the gas used (the density for a pressure thermometer, or the pressure for an expansion thermometer) be prescribed. It appears then that the standard of practical thermometry consists essentially in the reference to a certain numerically expressed quality of a particular substance." The question "Is there any principle on which an absolute thermometric scale can be founded?" is raised by Thomson, and then answered, "by showing that Carnot's function (derivable from the properties of any substance whatever, but the same for all bodies at the same temperature) or any arbitrary function of Carnot's function may be defined as temperature, and is therefore the foundation of an absolute system of thermometry."

That Carnot's function is simply and solely a function of temperature follows directly from the well-known proposition: The efficiency of any theoretically perfect engine is independent of the substance employed in driving it, and is simply a function of the two limits of temperature betweeen which the engine works. For if we write the expression for the efficiency for the particular case, in which the perfect engines have the infinitely small range of temperature dt, namely:

$$\text{Efficiency} = \frac{\left(\frac{dp}{dt}\right)_v}{J\left(\frac{dQ}{dv}\right)_t} dt,$$

J being the numerical constant known as Joule's equivalent $\left(\frac{dp}{dt}\right)_v$ the rate at which the pressure varies with the temperature when the volume remains constant, and $\left(\frac{dQ}{dv}\right)_t$ the rate at which the heat, furnished to or abstracted from the body, varies with the volume when the temperature remains constant, we will readily see that $\left(\frac{dp}{dt}\right)_v \div \left(\frac{dQ}{dv}\right)_t$ is the only variable factor in the expression for the efficiency, and that consequently this factor must be a function of the only quality—temperature—with which (as the above proposition informs us) the efficiency varies. This factor $\left(\frac{dp}{dt}\right)_v \div \left(\frac{dQ}{dv}\right)_t$ is Carnot's function, its reciprocal multiplied by Joule's equivalent J, is what Thomson took for the foundation of his absolute system of thermometry.

The numerical values of this function for any given temperature, such as the freezing point of water, can be determined for any one of a series of bodies of the most widely different properties, provided only that the bodies are all at the given temperature, and that the relations between the pressure, volume and temperature of each body, near the given temperature are known. It is because of this last condition that the numerical determinations* have been principally and best made on such simple, well-known bodies as gases and vapors. The values obtained differ more or less, but the best of them is believed by Thomson to be very near the true value.

The numerical values of Carnot's function having been once accurately ascertained, the arbitrary function of it which is to form the basis of the scale of absolute temperature, can also be calculated. It is of course desirable that the form of this arbitrary function be such as to facilitate reductions from the absolute scale to the scale of the standard air thermometer in which the past observations of temperature have been expressed. This fortunately can be most easily done with sufficient accuracy for most practical purposes, for Thomson found that the numerical values of Carnot's function, which he had obtained for different temperatures, varies very nearly inversely as the readings of a standard air thermometer, whose freezing and boiling points were respectively marked 273.7° and 373.7°. The reciprocal of Carnot's function multiplied by the numerical constant known as Joule's equivalent was, therefore, assumed by Thomson as the basis of an absolute system of thermometry. The numerical value T of temperature expressed absolutely may therefore be obtained from the equation

$$T = J \frac{1}{\left(\frac{dp}{dt}\right)_v \div \left(\frac{dQ}{dv}\right)_t}$$

The best empirical formula which has thus far been deduced for the relation between the absolute temperature T and the readings t of a standard air thermometer of constant volume, of which the freezing and boiling points are respectively marked 0° and 100°, is as follows:

$$T = 273.89 + 1.00026\, t - 0.0000026\, t^2$$

when $t=0$ $T=273.89$,

which is probably correct within a small fraction of a degree.

The second error above mentioned consists in assuming the co-efficient of dilatation a, used in the general formula $pv = c\,(1 + a\,t)$ for gases nearly perfect, to be the ratio of the increment of volume for one degree rise in temperature (the pressure being constant) to the volume which existed at the beginning of the rise of temperature. This can, perhaps, be more clearly expressed by the aid of symbols.

Let v_0 = vol. of gas for temp. $t=0$

v = " " " t

v_1 = " " " $t+1$

then the error above mentioned consists in assuming

$$a = \frac{v_1 - v}{v} = \text{constant.}$$

The correct expression would be

$$a = \frac{v_1 - v}{v_0} = \text{constant.}$$

It is this last value which is constant throughout the ordinary range of temperature, and from which the formula

$$v = v_0\,(1 \times a\,t)$$

can be obtained which accords with experiment. On the other hand, the first and erroneous assumption gives the incorrect and misleading formula

$$v = v_0\,(1 + a)^t$$

* See Clapeyron, *Journal de l' école Polytechnique* (1834), vol. XIV, p. 170, and *Pogg. Ann.*, vol. XLIX, p. 446, Thomson, "On an Absolute Thermometric Scale," founded on Carnot's theory of the motive power of heat, and calculated from Regnault's "Observations on Steam," *Proc. Camb. Phil. Soc.*, June 5, 1848, and *Phil. Mag.*, Oct., 1848; also, Thomson and Joule, "On the Thermal Effects of Fluids in Motion," Sec. III, "Evolution of Carnot's Function," *Phil. Trans.*, vol. CXLIV, p. 347. (1854.)

DWELLING HOUSES: THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS.

By Prof. W. H. CORFIELD, M. A., M. D. (Oxon).

From "Journal of the Society of Arts."

II.

A very important matter in the sanitary administration of large towns, and an important matter for the consideration of every householder, is the regular and frequent removal of house refuse known as "dust." This consists chiefly of ashes and cinders; but, unfortunately, the dust bin or ash pit is only too convenient a receptacle for all kinds of refuse matters, including kitchen *debris*, and so, in a large number of instances, these receptacles, especially in hot weather, become excessively foul, and an abominable nuisance. If the dust were removed daily, as it should be wherever this is practicable, the mixture of organic matter with it would not be of great importance, but where this cannot be done, it is very necessary to insist that the dust bin shall be used for nothing but ashes, and that all organic kitchen refuse, such as cabbage leaves and stalks, shall be burnt. This can be done without any nuisance by piling them on the remains of the kitchen fire the last thing at night; thus they are gradually dried during the night, and help to light the fire in the morning. When dust is valuable to those who contract to remove it (for this work is generally let out to contractors by the parish authorities, although in several instances it is now being done with great advantage and saving to the ratepayers by the parish workmen themselves), there is no difficulty in getting it removed. The contractors are only too glad to get it, and even prosecute people who keep any of it back for their own uses. The cinders and ashes from dust bins are largely used in brickmaking, and so when the building trade is slack dust becomes worthless. The contractors, instead of paying for it, require to be paid considerable sums to take it away, and the less they take away, and the less frequently they call for it, the more advantage do they get out of their bargains. This has been the case for some years, and in one parish alone, that of Islington, where I was formerly Medical Officer of Health, the difference that it made to the sanitary authority in one year as compared with another only six years before, was no less than £6,257; whereas in the former year the sanitary authority received £2,200 from the contractors, in the latter they had to pay £4,057. No doubt, the best plan to get rid of such refuse matters would be to put them outside the door early in the morning in a box or bucket, to be called for every morning by the contractor's men, and this is already done in some places. Otherwise it is necessary for every householder to take care that the dust bin does not become a nuisance to himself or his neighbors, from too large an accumulation being allowed to remain in it, or from improper matters being thrown into it. Dust receptacles ought not to be kept inside of houses, as they very frequently are. Neither ought they to be built against the wall of the house, unless cased with an impervious layer of cement, to prevent emanations from them percolating through the walls into the interior of the house. They ought always to be covered with a sloping roof, so that the rain may run off; if rain water is allowed to get into them, they are much more likely to become a nuisance. Rain water pipes ought not to be carried through dust bins, for foul air from the latter will get into the pipe through a leaky joint, or a damaged place, and ascend it, causing a nuisance in one of the upper rooms, or elsewhere. I have known a serious nuisance caused in this way.

REMOVAL OF EXCRETAL MATTERS BY CONSERVANCY SYSTEMS.

Under the systems the excretal matters are either collected without any admixture, in receptacles known as cesspools, or they are mixed with ashes, and the other house refuse, forming what is called a "midden heap," and of these two old plans all the dry closets, pail and tup systems, etc., may be said to be modifications. Cesspools were formerly largely used. especially for houses built on porous soils. A pit was dug into which the excretal matters were discharged and allowed to percolate away into the soil—frequently into neighboring wells. Often there was not only no pretence at making this pit impervious, but every facility was given to allow of the percolation of the foul water, etc., into the soil around. Thus the walls (when there were any) were made merely of rough blocks of stone placed one upon another. In some instances, these pits were not opened for many years together. Such cesspools were constructed long before water closets came into use, and were often retained after the introduction of these. In many instances they are placed underneath houses, and under the basements of large houses there are sometimes several of them. They form a serious nuisance, lasting for many years, as foul air from them finds its way into the house, even when there are no waste pipes directly connected with them, as there generally are, and thus they are very dangerous to health, even supposing that they are so placed as not to contaminate the water supply. In some towns it was, positively, formerly a practice to dig them down until a spring, or water of some kind was reached, in order that they might not require to be emptied. In all old houses it is imperative to search diligently even for unused cesspools, and to trace the course of every pipe from every part of the house. In many instances, openings from the basement floor lead into disused cesspools, even in houses that have been drained, and the cesspools presumably abolished. A basement drain is not unfrequently allowed to discharge into an old cesspool, after a properly constructed sewer has been made to receive the refuse matters from the water closets. This is a source of great danger to the inmates of the house.

In some instances, however, cesspools are made of brickwork set in cement and lined internally with a layer of cement, so as to be impervious to water. They then require to be emptied periodically, a process which often causes a considerable nuisance, and they require, moreover, to be at a considerable distance from the house, and to be disconnected from the house drains and sewers in a manner that will be described in the next lecture. Not unfrequently, however, they are placed directly underneath the house or under the court yard, as is commonly the practice in Paris and many other continental cities and towns. Pipes are laid straight into them from the various stories of the house, and sometimes these are the only ventilating pipes through which foul air can escape. Occasionally they are made to overflow into sewers or drains, and sometimes a kind of strainer is placed inside them, so that the solid refuse may be collected, and the liquids allowed to escape into a sewer or drain. They used formerly to be emptied by hand and bucket, thereby causing an abominable nuisance, and the workmen employed for this purpose were frequently suffocated by the foul air, and suffered from inflammation of the eyes caused by the ammoniacal vapors Of late years, they have been emptied by hose into airtight carts, from which the air has been previously exhausted by a powerful pump. This process, of course, causes less nuisance, and is not dangerous to the men employed, but, even with these improvements, the system is a very disagreeable one.

In some towns large midden heaps are still in vogue. The mixture of ashes and other house refuse with the excretal matters produces a drier mass, which, if not exposed to the rain, is considered to cause less nuisance than cesspools; but if dust bins are bad and are nuisances, as they most certainly are in a very large number of instances, midden heaps must be very much worse. Refuse matters become nuisances and injurious to health when they are allowed to remain in the vicinity of habitations. In all towns where refuse matters are not removed immediately there is a high death rate, and especially a high children's death rate, and in all towns (as Dr. Buchanan has shown in the ninth report of the Medical Officer of the Privy Council) where refuse matters are removed more speedily than they were formerly, the general death rate has been lessened. The improvements that have been made, then, in these conservancy systems, consist in diminishing in various ways the size of the receptacles, so that the refuse matters cannot be collected in so large an amount, or kept for so long in and near the house, and in making receptacles impervious to water, so that liquids cannot escape from them into the soil around, nor water get into them. Sometimes the receptacles are drained into the sewers, so that the liquid part can run away, leaving the contents of the receptacle drier. In other cases they are not. The improvements in cesspools, then, have consisted in making them smaller and smaller, and, lastly, moveable—the *fosses mobiles* of the Continent; the pans, pails, tubs, etc., of some of our large towns. These movable receptacles are placed underneath the seats of the closets, fetched away when full by the scavenger, and replaced by the empty ones. They are, or ought to be, fitted with air-tight lids, so that as little nuisance as possible may be caused by carrying them to the carts; but, as may be expected, in many instances they are allowed to get too full, and a great nuisance is often caused in the houses. Nevertheless, this plan is a considerable improvement upon the plan of large buried cesspools. One of these pails that is largely in use is Haresceugh's spring-lid receptacle, a specimen of which may be seen in the Parkes Museum.

Similar improvements have been made in middens. The pits, in which the excretal matter and ashes are collected, have been made smaller and smaller, and impervious to water, until, at last, in some towns, they are above the ground, and consist only of the space beneath the seat of the closet made into an impervious receptacle, and usually drained into a sewer or drain. This, of course, necessitates their being emptied frequently, which is done by hand and spade labor. A capital plan is that adopted by Dr. Bayliss, the Medical Officer of Health for the West Kent Combined Districts, in which there is a ventilating shaft from the back part of the receptacle, rising above the roof of the closet. This allows the foul air to escape above the roof, while fresh air enters through openings cut in the door. Sometimes boxes or pails are used and removed periodically, as in the case of the tubs and pails, previously described as moveable cesspools, the only difference being that ashes, &c., are thrown in with a scoop, or by means of some self-acting apparatus. A contrivance which is now largely used, in towns where this system is in vogue, is Morell's cinder-sifting ash-closet, of which I have a model here. (A full-sized specimen may be seen in the Parkes Museum). The ashes are thrown on to the sifter, through the interstices of which the fine ash passes into a hopper, and the cinders fall off and may be collected and used again. The hopper is connected with the seat in such a manner that the weight of the person moves the seat a little, and jerks some of the fine ash down into the lower part of the hopper, from which it is thrown into the midden by another jerk when the person rises. Another contrivance of this kind is Moser's, which is also of very simple construction, and others are Taylor's and Wier's. The Eureka and Goux, and some other systems are varieties of the pail system in which an absorbent of some kind or another is used.

We now come to a consideration of the dry-earth system, which was brought into prominence by the Rev. Henry Moule. It consists in throwing over the excretal matters a certain quantity of dried and sifted earth, when an absorption takes place, and a compost is produced which is perfectly inoffensive to the sense of smell. The earth may be dried and used over and over again for five or six times, or even more, and any earth except chalk or sand will answer the purpose. It may be thrown by hand, or by a self-acting apparatus moved by the weight of the person, or by the door of the closet, or by a pull-up apparatus similar to that ordinarily used in water-closets. It will be seen at once that with this system there is not only something to be taken away, but something to be brought into the towns and into the houses—the dried earth; and this constitutes a very serious objection. However, it is an objection that might perhaps be waived, if the system could be satisfactorily worked on a large scale and by careless persons, for it is essential, in a large town at any rate, that a system for the removal of refuse matters must be used which can be worked by the most careless persons. When we consider that, if the supply of earth were to fail for a day, a serious nuisance would be caused in every house; that if a servant throws a pail of slops into an earth-closet it becomes a cesspool; that the apparatus may get out of order, so that earth is not thrown in even though the hopper be full; and that an enormous quantity of earth would be required in every large town, we shall see that, at any rate for large towns, it is impracticable; and when added to this, we find the fact that one great argument in favor of the system, the supposed value of the manure produced, is entirely fallacious, it having been shown by the Sewage Committee of the Britsh Association, that the compost, even after passing six times through the closets, can only be regarded as a rich garden soil, and would not pay the cost of carriage even to a small distance; that, in fact, in the disintegration and decomposition of the organic matters that takes place in the mass, almost all the nitrogen is got rid of in some way or another, we see that one great argument for its use in towns disappears. We must remember, too, that deodorization is not necessarily disinfection, and, as Dr. Parkes pointed out, we do not know that the poisons—say of typhoid fever and cholera—are destroyed by being mixed with dried earth. It is even possible that they are preserved by it, and there can be no doubt that if the earth is not sufficiently dried, or if water is thrown on the mass, considerable danger would arise if the poisons of such diseases were present. While, however, the system is impracticable for large communities, it is one that has been found very useful indeed under suitable circumstances. It is useful for temporary large gatherings of people at flower shows, cattle shows, race meetings, volunteer reviews, &c., especially where there is a strict supervision, and where persons can be told off to attend to the distribution of the earth. Earth-closets are suitable for use in villages and country houses in the open air, but they ought not, in my opinion, to be placed indoors even in the country. Where the earth can be collected and dried on the spot, and the compost afterwards used upon the garden, the plan has been found very useful if only sufficient care be exercised, and no nuisance need be produced.

To sum up with regard to the conservancy plans, their very name condemns them one and all, for use in large towns at any rate, or in the interior of houses. One of the most important of sanitary principles is, that the refuse matters should be removed as speedily and as continuously as possible from the neighborhood of habitations, and the principle of all conservancy systems is that the refuse matters are to be kept in and about the house, at any rate, as long as they are not a nuisance, which of course means that, in a large number of cases, they become a serious nuisance. It is also obvious that the carriage of the refuse matters entails considerable cost under any of these systems, and so the less frequently they are removed the less does it cost, and what is detrimental to the life of the population becomes advantageous to the ratepayers. If the manure so collected were valuable, it might, of course, be made to pay the cost of collecting, but this is not the case as a rule, the only instance in which any of these systems have been made to pay being where the excretal matters have been collected in pails or tubs, unmixed with anything which would lessen their value. With all these systems, too, it is necessary to have some method for disposing of the slops and foul water generally, which cannot be allowed to run into the water-courses, as it would contaminate them, and so it is necessary to have sewers, the construction of which will be described in the next lecture.

As opposed to the conservancy systems, we have the water-carriage system, by means of which the refuse excretal matters are conveyed away in the foul water by gravitation through the sewers, and are thus removed from the houses as speedily and cheaply as possible by means of the pipes, which must in any case be provided in towns, to get rid of the foul water. The sewage is increased in bulk, but it is not rendered perceptibly fouler by this admixture. Indeed, as a rule, the sewage of a town supplied with water-closets is less foul than that of a town supplied with middens. Although, however, sewers are necessary in towns to carry the foul water away, in country places the slop water may be allowed to run into the surface drains, provided they do not pass near wells, and this is best managed by means of a contrivance which I shall exhibit in another lecture.

The water-carriage system has disadvantages of its own, and requires special precautions to be taken, which, so far as they are connected with dwelling houses, will be described in the next two lectures.

SEWERAGE—MAIN SEWERS AND HOUSE BRANCHES, TRAPS, VENTILATION, &C.

Even where conservancy systems are used for the removal of refuse excretal matters, it is necessary to have some contrivance by means of which the foul waters can be got rid of. In country places, it may be discharged into ordinary agricultural drains laid beneath the garden. It then percolates into the soil, and serves to fertilize the crops. If, however, such waste water is thrown gradually down the traps and into the drains a small quantity at a time, the water escapes through the junctions of the first few pipes, and the fat and other solid matters become deposited in them, and soon choke up the pipes; so that it is necessary to collect the slop-water, and discharge it at intervals. The best contrivance for this purpose is Mr. Rogers Field's flush tank, of which I have here both an actual specimen and a large working model, kindly lent by Mr. Field. The slop-water is discharged over a loose iron grating at the top, and passes through a funnel-shaped aperture with a siphon bend at the bottom of it, which can also be lifted out, into the tank below. The discharge-pipe from this tank does not start from the top of it, but very near the bottom, is carried upwards to the top, and turns over and passes downwards to its outlet, which is at a lower level than the point from which the pipe began. This pipe is made in the earthenware end of the tank itself. Thus it will be seen that a siphon is produced, so that when the tank is filled to the top, and the shorter limb of the siphon also filled up to the bend, a sufficient quantity of water thrown in suddenly will start the siphon, and so empty the tank of its contents to the level from which the lower limb starts inside the tank. The discharge end of the siphon has a weir placed across it with a notch in it. By means of these contrivances, not only will a smaller quantity of water start the siphon, but a false action, which was found occasionally to take place, and which caused the water to dribble away without the tank being emptied, is prevented. Thus the whole body of water contained in the tank is made to rush through the drains, and the difficulty spoken of above is avoided. The tank also acts as a very good fat trap. In towns, however, it is necessary to have sewers for the removal of the foul water. Sewers ought to be impervious to water, so that their contents may not percolate into the soil around, and so drains which are made to dry the soil are obviously not fitted to be used as sewers. The larger sewers are usually made of bricks, and built with an oval section, this being preferable to the circular, and of course far better than any rectangular section. The bricks should be of the very hardest kind, and set in cement, and it is advisable to build the "invert," or lower part of the sewer, upon invert blocks made of stoneware. For smaller sized sewers stoneware pipes are the best. They should always be used for sewers not greater than eighteen inches in diameter. Larger sewers than these are cheaper made with bricks set in cement. Stoneware pipe sewers would be much more used than they are in towns, but for the fact that the estimated size of the sewers generally is usually larger than is required, and much larger than would be required if the rain and surface water were carried away by separate drains. The pipe of the sewer only requires to be large enough to carry away the water that can be discharged into it, and anything beyond that size is an absolute disadvantage, as it makes it more difficult to flush the sewers properly, for a larger pipe is insufficiently flushed by a quantity of water that would easily flush a smaller one. For flushing purposes it is best to have an arrangement by which a considerable quantity of water is delivered into the sewer at once, so that it may fill it, or nearly so. The same quantity of water delivered more gradually does not produce by any means the same effect. In laying sewers, whether main or house sewers, provision should always be made for making new connections, without cutting into the pipes. This may be done by putting in junctions at various points—a plan especially suited for private estates, where the points at which junction may be wanted will suggest themselves. With street mains more ample provision should be made. Mr. Jenning's pipes, which allow of the sewers being opened at any point without cutting the pipes, may be used. The pipes, in fact, have no sockets, the place of the sockets being supplied by divided rings, in one half of which the pipes are laid at their junctions, while the other half covers the upper part of the junction. With ordinary socket pipes, Messrs. Doulton's lidded pipes may be used with advantage. In these a third of the pipe can be taken off along the whole length of the pipe, and so junctions can be made, the pipes inspected, and cleaning rods pushed down them when necessary. The "capped" pipes made by Messrs. Jones & Company, of Bournemouth, are also useful. They are constructed in the following way:—A semi-circular or semi-elliptical hole is cut out of each pipe at its end, so that when the pipes are socketed a circular or elliptical hole is left at the junction between the two. These holes are closed by means of lids made for the purpose, which may be removed at any time, for the purposes of inspection, inserting a junction, &c. The above remarks apply to house branches as well as to main sewers, and it is very important not to omit the insertion of inspection pipes, of some kind or another, at proper intervals and suitable places, in house sewers, especially those of large mansions.

The main sewers should be freely ventilated at the level of the streets. All attempts to ventilate them in any other manner have been, without any exception, signal failures. If the ventilators, whether of main or of branch sewers, cause a nuisance, it is because there are not enough of them, or because the sewer is either badly laid or not properly flushed. In country places especially, cesspools are often the destination of the house sewers. Cesspools should never be made where it can be helped. It is far better to use the sewage on the land than to collect it in cesspools. However, in some places, cesspools are necessary, in which case they should always be made impervious to water, by being built of bricks set in cement and rendered in cement. The cesspool should not be under the house, but at some distance, and it must be ventilated. If near to the house, the ventilator should be carried up outside the wall of the house, and above the ridge of the roof. If at some distance, it may be ventilated either by means of an open galvanized iron grating, or by means of iron pipes carried up a tree and covered with wire network at the top. The cesspool should not overflow into a stream, or drain running into a stream, but on to the surface of the ground; and it is folly to build a second cesspool, as some people do, for the first one to overflow into, for, by the same argument, one might build any number—one after the other. Brick sewers should never be used under houses. The foul water soaks through them into the soil, and sediment is liable to accumulate in them. Rats eat their way through them, displacing the bricks and wandering about the house, and so not only does foul water get out of them into the soil, but foul air finds its way wherever the rats go, besides the fact that rats carry filth from the sewer itself about the house, and into the larder if they can get there. In this way, I have no doubt whatever, that milk and other foods have disease poisons frequently conveyed to them. Sewers made of glazed stoneware pipes should always be used for houses, except in cases where it may be better to use iron pipes, and they should always be laid outside the walls of the houses whenever it is practicable. They may require to be laid in a bed of concrete, as for example, where there is much made ground, or to be laid on hollow invert blocks in very wet soils. They should be jointed with cement, or, where a settlement is feared, with clay, finishing with a ring of cement. Clay alone is not advisable, as it is apt to get washed out of the joint, in which case the water runs out into the soil, and the solid matters accumulate in the sewer. If pipes, with Stanford's patent joint, made by Messrs. Doulton & Co. (of which I have some examples here) are used, no cement is required. The ends merely have to be greased and fitted into one another. These pipes must be laid straight, or they will not fit together, and at bends it is often requisite to use ordinary socketed pipes. The fall of a house sewer should at least be 1 in 48, but a more considerable fall is preferable; 9-inch pipes may be used for very large mansions, especially if outbuildings are connected with the sewer, but, as a rule, for private houses 6-inch pipes with 4-inch branches are amply large. The junction of the branches should never be made at right angles, but always at an acute angle, and of course in the direction in which the water is going. At the end of the house sewer, in the main sewer, or cesspool, a swinging flap made with galvanized iron is frequently placed, with the view of keeping rats out of the house sewers. It may be of some use for this purpose, but is of little use for preventing the entrance of foul air, and as may be expected, these flaps are often out of order. It is also usual to place a water-trap of some kind upon the house sewer before it enters the main or cesspool. The kind formerly most used was what is known as the dipstone trap. The drain was deepened at the spot, and a piece of stone or slate inserted right across the drain from side to side, and reaching from the top down into the deepened part, two or three inches below the level of the bottom of the sewer. Water of course always remained in the deepened part, and so the dipstone running right across the drain dipped about two or three inches into this water. As it reached also to the top, and was built in, it obviously prevented the passage of the sewer air from the main sewer or cesspool into the house sewer, except, at any rate, that which could pass through the water in the trap. These traps were usually made rectangular, and were often very large, so that they were practically cesspools, and they still go by this name in some parts of the country. They may be much improved by making the end nearest to the house vertical, giving the opposite one a gentle slope, and fixing the dipstone, not vertically, but slanting in the direction in which water goes—rounding off the inside with concrete rendered in cement, so that there are no angles or corners. Thus the water falls vertically into the trap and flows out through a gentle incline. In such a trap very little accumulation occurs. Stoneware siphon traps are, however, now almost entirely used. They are frequently made with an upright piece from the lower part of the siphon, which may be continued by means of straight pipes up to near the surface of the ground, for the purposes of inspection, and of cleaning out the siphon should it get blocked up. This inspection opening is now sometimes made at the end of the siphon which is intended to be placed next to the house, so that if pipes are carried from it up to the surface of the ground, and an iron grating put on to it, a passage is formed which, under ordinary circumstances, acts (if precautions are taken which will be presently mentioned) as an entrance for air into the house sewer. The siphons also are now made with the limb into which the house sewer opens nearly vertical, while the opposite limb has a gentle slope upwards—the effect produced being that already mentioned. It is a considerable improvement, although not absolutely necessary, to increase the air inlet into the sewer at this point, that is to say, immediately on the side of the siphon trap, and instead of merely having a pipe taken up to the surface of the ground, to have a man-hole built in brickwork, and with channel pipes instead of whole pipes running along the bottom of it into the siphon. The channel pipes and one or two pipes beyond should be laid at a considerable fall, so that the water may rush down into the siphon and clear it out as much as possible. Branch pipes may be made to join the main in the man-hole by means of channel pipes, or even by whole pipes discharging into a gutter built above the channel pipe; or they may of course be taken into the house sewer at any point of its course. The man-hole may be covered by a galvanized iron-locked grating, if it is in such a position that gravel, &c., is not likely to get into it, but if in an area it is better to cover it with a locking iron door, and to have one or two 6-inch ventilating pipes from its upper part carried under the pavement area to the wall, up in the wall a short distance, and then opening out by gratings flush with the surface of the wall. A junction pipe should be fixed immediately beyond the siphon and pipes brought from it through the wall of the man-hole, the end being filled with a plug, which can be removed for the purpose of cleaning the sewers beyond the siphon if necessary, or various earthenware disconnecting traps may be used. Potts's Edinburgh chambered sewer trap has the advantage of having a large air inlet, and a considerable fall in the trap itself. In many instances, with sewers already laid, sufficient fall cannot be got to introduce these traps. Weaver's trap is really a siphon, as already mentioned, with an upright air inlet leading into the limb of the siphon nearest to the house. Beyond the siphon an aperture is provided by means of which the main sewer, or cesspool beyond, can be ventilated, or which, if merely plugged, may serve as an inspection pipe, through which rods can be pushed, if necessary, down into the main sewers or cesspool. In Buchan's and Latham's traps the fall is quite vertical.

Stiff's interceptor may be described as a siphon-shaped trap, with a double dip, so that it has three compartments, with an open grating for the middle one. If any sewer air should pass under the first dip, it cannot get under the second, which is deeper, but will escape into the open air through the grating. Two inspection openings are provided, which may be also used as ventilating openings—the further one to ventilate the main sewer or cesspool, if necessary at this point, by means of a pipe running to the top of the house, and the one on the house side of the trap may be used as an air inlet. Professor Fleeming Jenkin has introduced the plan of using two siphon traps with an open grating between them. Dr. Woodhead has modified this by having a large earthenware receptacle, which all the house pipes enter underneath a large iron grating, with two siphons beyond the receptacle, one after another, and an upright pipe with an open grating between them. There is also a smaller upright pipe, with open grating at the top between the receptacle and the commencement of the first siphon. It is unfortunate that we cannot do without a water trap at all in disconnecting the house sewers from the mains, and I certainly do not think that any sufficient reason has been made out for having two traps one after another. At the highest point of the house sewer, or, if necessary, at the end of one or more branches, there should be a ventilating pipe, four inches in diameter, carried up above the eaves of the house or above the ridge of the roof, and not under or near any bedroom windows. This may be covered with a little conical cap, or merely with a piece of wire network, or with a cowl (preferably a fixed cowl) if it is required to be ornamental. Whether this pipe be covered with a cowl or not, air will, as a rule, enter at the air inlet at the lower end of the sewer, pass along it through its whole length, and escape by the ventilating pipe or pipes just mentioned, and no foul air can accumulate in any part of the sewer. If any foul air escapes at the air inlets, it acts as a warning to show that something is wrong; the siphon is stopped up, or there is an accumulation of foul matter in it, or in the sewer somewhere. When all is going right, no foul air will escape by these openings. The ventilating pipes may be made of iron if only used as ventilating pipes. When used also as soil-pipes they are better made of lead, as will be further shown in the next lecture. Rain-water pipes may be taken directly into the house sewer or its branches without any trap, provided that their joints are well filled and packed, and that they do not open at the top near to any bedroom windows, otherwise they must discharge over the surface of the yard or area. The surface gulleys for yards, &c., may be stoneware siphon gulleys, provided with galvanized iron gratings, which are better than stoneware gratings, as they are less liable to break. They are sometimes provided with openings in the side above the level of the water for the admission of waste pipes, &c. Dipstone traps are sometimes used, but are objectionable. McLandsborough's gulley is sometimes useful. It may be described as an iron dip-trap with three compartments, having several openings, into which pipes may be taken above the surface of the water. Jennings' receiver is also often useful, especially where the trap has to be low down, and upright pieces placed one above another over it up to the level of the pavement. Pieces with openings are provided, so that drains coming from the inside of the house—the basement drains for instance—may be discharged into it, and so disconnected from the house sewer. Drains from the basement of a house ought not to open directly into the house sewer, but always into a disconnecting trap of some kind or another. Clark's gulleys are useful where much sludge is likely to be washed into the trap. They are provided with iron buckets that collect the sludge, and can be lifted out bodily. They are doubly and sometimes trebly trapped. The common bell trap, so often used, not only in areas, but in the basements of houses, is a most mischievous contrivance. It consists of an iron box with a pipe, which is connected with the sewer, standing up in it. The perforated cover of the box has an iron cup or bell-shaped piece fastened underneath it. Of course water stands in the box up to the level of the pipe which descends into the sewer. The bell on the perforated lid is so arranged that, when the lid or grating is in its place, the rim of the bell dips into the water around the vertical pipe. Even if the bell is in place, and whole, the trap is untrustworthy, because a very slight increase of pressure of air in the sewer will cause it to force its way through the small film of water into which the bell dips. It is objectionable because it soon becomes filled up with filth; and because, unless water is almost continually running through it, a sufficient amount evaporates to allow the sewer air to escape freely; but the great objection to it is that, when the cover is taken off, the bell is taken off too. The trap, such as it is, is gone, and the air from the sewer escapes freely into the house if the trap is inside the house. The covers are often taken off by servants, and left off, and are also frequently broken, and so the use of these traps should be discouraged as much as possible. The Mansergh trap is frequently useful in areas, as it serves also for the disconnection of the basement sinks, and provides a place of attachment for a ventilator for the house sewer. It consists of three compartments. Into an opening in the side of the first, the waste-pipe of a sink may be conducted. The water from this fills the first compartment up to the level of an aperture, through which it passes into the second, the pipe through which the water is conveyed into the first compartment being made to dip below the surface of the water in that compartment. Over the first and second compartments there is a loose iron lid with a grating over the second or middle compartment. From the second compartment, the water passes under a partition into the third, the outlet from which into the house sewer is above the lower edge of this partition, which itself extends from the top of the trap nearly to the bottom, so that it completely separates the air in the third compartment from that in the second, and dips beneath the level of the water in the two compartments. The top and sides of this third compartment are made of stoneware, so that it does not communicate with the external air, the outlet to the sewer being at one side, and an aperture to which a ventilating pipe may be attached in one of the other sides. Even if the last aperture be plugged up, and no ventilating pipe attached, any sewer air which can pass through the water from the third compartment into the middle one would escape by the grating into the open air, and could not get into the house, as the pipe from the house into the first compartment of the trap dips below the water. The cases in which it is more advisable to use this trap than ordinary siphon gulleys, will be mentioned in the next lecture.

WATER-CLOSETS, SINKS AND BATHS.—ARRANGEMENT OF PIPES, TRAPS, &C.

Water-closets.—The simplest form of water-closet is the common hopper closet, consisting of a conical basin with a stoneware siphon trap below it. There is nothing to get out of order in these closets, but they are liable to get stopped up through an insufficient amount of water being used in them, and the basins often get very foul from the same cause, and from the fact that no water remains in the basin. They are very often supplied with water by means of a $\frac{3}{4}$-inch service pipe, which cannot supply water enough to flush them properly. This pipe is frequently taken directly from a cistern supplying drinking water, or, even where the water service is constant, directly from the main water pipes provided with an ordinary stop-cock, or, perhaps, with a screw-down tap—a very mischievous plan, as the taps are frequently left turned on, and the water allowed to run to waste, sometimes emptying the cistern, and allowing foul air to get into it. When such pipes are taken direct from the main, the results are even more serious, as, if the water is, for any reason, turned off in the latter, foul air, and even liquid and solid filth, may be soaked up into the water mains, and contaminate the water supplied next. To this cause a very serious outbreak of typhoid fever in Croydon has been traced by Dr. Buchanan. The supply pipes for these closets should not be less than 1¼-inch in diameter, and should not be connected directly with the drinking water cistern or with the main water-pipe, but with a water-waste preventing cistern holding two or three gallons—the quantity required to flush the closet. I have here several specimens of such cisterns, lent by Messrs. Hayward, Tyler & Co., and by Messrs. Tylor & Sons. They are supplied from the nearest water cistern, or, in the case of a constant supply, from the main water-pipe—the supply pipe being guarded by a ball valve. The pipe from this waste-preventer to the closet is guarded by a valve, frequently the conical one known as the spindle valve, which can be raised by means of a lever worked by a chain and ring. When the chain is pulled, the spindle valve is raised, and the two or three gallons contained in the water-waste preventer are discharged into the hopper closet, while at the same the the ball valve is also raised by the lever, so that no water can come into the waste-preventer while the chain is being pulled. It will be seen that this and similar contrivances not only prevent direct connection between the water-closet and the drinking water of the cistern or main water pipe, but also prevent an inordinate waste of water. Other water-waste preventers will be mentioned shortly. An improvement on the ordinary hopper closet is the "Artisan" closet, made by Messrs. Beard, Dent, & Hellyer, in which the hopper is provided with a flushing rim, which is far better than the old plan of shooting the water in at one side of the hopper. In the "Vortex" closet, made by the same firm, the siphon is much deeper than in the "Artizan" closet, and the water stands in the basin. A two-inch supply pipe is necessary, the water being discharged by a flushing rim, and also projected into the middle of the basin, as it is clear that a greater force of water is required to flush out so deep a siphon On the other side of the siphon is placed a ventilating pipe to carry away any foul air.

We now come to various forms of "Wash-out" closets, the first being Jennings' "Monkey" closet. In this, a small amount of water remains in the basin, the opening out of which into the siphon is not at the bottom, as in the case of the hopper closet, but on one side. The advantage of this form of closet is, that it is not possible, as is the case with hopper closets, for careless persons to go on using the closet without flushing it with water, as the soil remains in the basin until it is flushed out. Hopper closets, on the other hand, may be used for a long while without any supply of water at all, and this is the way in which pipes frequently get stopped up. In the monkey closet the basin and siphon are all in one piece of earthenware. In Woodward's "Wash out" closet the basin is provided with a flushing rim, and the siphon is separate from the basin, so that it can be turned in any direction necessary. In Bostel's "Excelsior" closet the basin and the siphon are in one piece of earthenware, and the outlet at the back of the basin. The water-supply pipe is made to enter the basin by two branches, one on each side, and a flushing rim is provided. At the back of the basin is a vertical opening leading directly into the siphon, by means of which anything improperly thrown into the closet can be removed. An over-flow-pipe is also provided, but this is, in most instances, useless. Dodd's "Wash-out" closet is somewhat similar in shape to the others, but has a ventilating pipe attached to the discharge pipe immediately beyond the siphon. An inch and a quarter supply pipe should be used with these closets, and where there is less than six feet fall, one and a half inch pipes may be used with advantage. Fowler's closets are suitable for use in poor neighborhoods, especially when there is an insufficient supply of water. In this system, rain, sink and other waste waters are made to wash out the trap of the closet.

The closet apparatus most commonly used in the interior of houses is that known as the "pan" closet, and is a most mischievous contrivance. The basin is conical, and below it is placed a metal pan capable of holding water, into which the lower part of the basin dips. This pan can be moved by the pull-up apparatus of the closet inside a large iron box called the "container," placed under the seat of the closet, and into the top of which the conical basin is fixed. This "container" has a 4-inch outlet at the lower part of it, leading into a trap placed below the floor, the trap being generally a lead "D" trap, from which a 4-inch pipe passes to the soil-pipe, which conveys the refuse from the closets into the sewer. The great fault of the "pan" closet consists in the large iron "container," which is merely a reservoir for foul air, as it always becomes very filthy inside. When the pull-up apparatus is worked, the pan is swung from its position below the basin, and its contents thrown into the "container," the sides of which are splashed with foul matters, and cannot possibly be cleaned. Besides this, the container leads into the D-trap, which always contains foul matters, and gives off foul air into the container. At the same time that the contents of the pan are thrown into the container, foul air from the latter is forced into the house. This can only be partly remedied by providing a ventilating pipe for the container, and carrying it out of doors, but I have more than once seen a ventilating hole drilled into the container, and no pipe attached to it, so that foul air from the container was driven out with a puff that would blow out a candle, each time that the closet was used, and this in closets immediately connected with bedrooms. The D-trap should not be used at all either under closets or sinks. It consists of a lead box shaped like the letter D, placed thus, ᗜ. The outlet pipe starts close to the top at one end, and the inlet pipe passes down to an inch or so below the level of the lower part of the outlet. Of course water remains in this trap up to the level of the outlet, so that the inlet pipe dips into it an inch or more. The D-traps are never washed out thoroughly at each use of the closet. A deposit of foul matter takes place in them, and foul air is generated. This gradually corrodes the lead, and eats holes through it at the upper part of the trap. I have here several specimens of D-traps with holes eaten through them by the foul air. Such holes, of course, form a means of escape for the foul air from the sewer into the house. The trap is generally made of sheet lead, and not cast in one piece of lead; but an improved form has been made by Messrs. Gascoyne, which is cast in one piece, and in which the inlet pipe is placed at one end, so that there is no space left between it and the end of the trap, for paper, &c., to accumulate in. Instead of a D-trap, where a lead trap is used, it should be an S-trap or P-trap of 4-inch cast lead. This is flushed out by each use of the closet. A lead tray is usually placed on the floor underneath the closet apparatus, the trap being placed sometimes above and sometimes below it. The object of this tray is to prevent any overflow from the closet soaking into the floor and perhaps through into the ceiling below, causing serious annoyance, and perhaps a great nuisance. This tray is commonly called the "safe" of the closet, but, as generally constructed, any other word in the language would be more applicable to it. It is, of course, provided with a waste pipe, and this waste-pipe is almost invariably carried into the D-trap, when there is one below the safe, but it is not unfrequently carried straight into the soil-pipe, with or without a siphon bend on it. When carried into the D-trap, it is usually made to enter below the surface of the foul water therein contained, but I have not unfrequently seen them carried straight into the top of the trap, and so form a passage for foul air into the house. They ought not to be connected with any part of the water-closet apparatus, trap or soil-pipe, but ought to be carried straight through the wall to end in the open air, being merely provided with a small brass flapper to keep draughts out. The waste, or overflow pipes of cisterns, are frequently carried into the D-traps of closets, in which case foul matters get washed into the inside of these pipes, and foul air from them contaminates the water in the cisterns. This is even a greater evil than the last, and the waste pipes of all cisterns, but more especially those used for the supply of drinking water, should, as stated in a previous lecture, be made to end in the open air.

We come now to valve closets, the numerous varieties of which are modifications of the original Bramah's valve closet. In this the aperture at the lowest part of the basin is closed by a water-tight valve, which can be moved in a small valve box, placed immediately below the basin, by means of the pull-up apparatus—the valve box itself being connected below with the trap. Thus, the necessity for the large iron container, so objectionable a part of the pan-closet, is done away with, and its place taken by a small box, in which the valve moves. As, however, the valve is water-tight, provision is made for the overflow of water from the basin, in case the latter should be filled to full, either by slops being thrown into it, or by the water continually running from the supply-pipe in consequence of a leaky valve. The overflow pipe starts from one side of the basin in which holes leading into it are peforated. It is then, as a rule, carried downwards into the valve box, having a small siphon bend on it before entering. The water from the supply-pipe, as it enters, is made to flow round the basin by an inner plate, generally made of metal, called the "spreader," or still better, in the improved form of valve-closet by means of a flushing rim. Thus, some of the water at each use of the closet passes through the holes leading into the overflow pipe; the object of this being to keep the siphon on that pipe charged with water, as it is clear that if this siphon is not charged, the overflow pipe ventilates the valve box, that is to say, the space below the valves, and the surface of the water in the trap below into the basin of the closet. Now, as a rule, the siphon trap on the overflow pipe does not remain charged with water, and even if it does, is of little use, for the following reasons—when by the pulling up of the handle the valve is made to move suddenly in the valve box, air from the latter is forced out through the water in the siphon bend of the overflow pipe, as any one can see, who will take the trouble to place a piece of moist tissue paper over the hole in the side of the basin leading into that pipe, and then work the handle of the closet. Thus foul air from the valve box is driven into the basin, even when the siphon on the overflow pipe is charged. Furthermore, as the mass of water in the basin rushes down through the valve box into the trap it carries the air along with it, and when the valve is closed runs out of the valve box, drawing air through the overflow pipe, and displacing the water in the siphon, which is in many cases left quite uncharged. Various remedies have been proposed for this. In Bolding's "Simplex" valve closet a small pipe is carried from the water-supply pipe into the overflow just above the siphon, with the view of supplying water direct to the siphon each time the closet is used. In Jennings' valve closets the overflow is trapped by means of a patent india-rubber ball trap, which is something like a Bower trap upside down. It is constructed so that the overflow water can displace the ball from the end of the water-pipe, and flow away round it, but any pressure of air from the valve box would only cause the ball to fit more closely against the end of the overflow pipe. In the valve closet made by Beard, Dent, and Hellyer, the overflow pipe is made much larger than usual, and the siphon deeper, so that it holds a larger quantity of water, and at the same time a ventilating pipe is inserted into the valve box, and should be carried through the wall to the outer air. By this means no accumulation of foul air in the valve box can take place, and any air that is drawn into it, while the water is passing through it, comes in through the ventilating pipe instead of through the overflow. It is quite right to ventilate the valve box, but the best way to deal with the overflow pipe is to disconnect it altogether from the valve box, and either carry it through the wall, placing a brass flap on the end of it, or to let it end over the waste pipe of the safe. Indeed, it is hardly necessary to have an overflow pipe at all, as if the basin does get full, all that will happen is that the water will flow over the top of it into the safe and run away. The advantage of this plan is that the existence of a leaky valve is found out immediately, and the disadvantage is that it is liable to wet the end part of the seat and apparatus below it. Lead D-traps are generally placed under these closets, but this should never be allowed. Siphon traps should always be used, for the reasons already mentioned. Some valve closets are made with a galvanized iron siphon trap that is to be placed wholly or partially above the floor, and is provided with a screw cap that can be taken off for the purpose of cleaning; such closets are made by Messrs. Tylor & Sons, and Messrs. Jennings. The latter also make closets, which may be called "plug" closets, the best known variety having the basin and siphon ball trap all in one piece of china. The plug closes the entrance from the basin into the siphon below, and is connected by a rod with the handle, which is vertically over it. By means of an india-rubber flange the plug is made to fit water-tight into the entrance of the siphon, and a body of water is kept in the basin above it, up to the level of the overflow, which is either made through the plug and the rod joining it with the handle, or by a separate trapped channel along side of it. A plug is also made to contain the patent ball trap mentioned above. It will be seen that in these closets, no valve box is necessary, and there is only a small air-space between the water in the trap and that in the basin. These closets are also made without any trap at all, in which case the overflow of the basin is carried, by a pipe, straight through the wall. Such trapless closets are often very useful on the ground floor, where the soil-pipe can be carried straight through the wall, and disconnected from the sewer by a ventilating trap outside.

We must now consider more in detail the arrangements for the supply of water to the basin. The simplest form of water-waste preventer has already been mentioned, but it must be remembered that the commonest plan for supplying closets with water, is to place a spindle valve in the bottom of a cistern somewhere above them, so as to guard the entrance into the pipe leading to the basin of the closet, and to work this valve by means of wires connected with the pull-up apparatus. The great disadvantage of this apparatus is that the wires get stretched by use, and have to be shortened from time to time. There is, obviously, also no provision against waste of water, for the water will run as long as the handle is held, or fastened up, until the cistern is empty. Neither is there any "regulator" to ensure a sufficient supply of water being delivered to the closet each time that the handle is pulled up, whether it is held up or not. I have here one kind of valve which achieves these two objects (lent by Messrs. Tylor & Sons), fixed in a cistern with glass sides, so that you may see its action. When the handle of the closet is worked the valve is raised, and if the handle is let go, the valve does not fall directly but gradually, so as to allow a certain quantity of flow out into the basin of the closet. But if the handle is held up (or down in the case of a ring and chain, as here) a metal weight which was carried up with the valve falls, and stops the flow of water. These valves may be used as cisterns, and connected with the pull-up apparatus by wires, or they may be placed in the small waste-preventing cistern already described, with the view of ensuring the use of a definite quantity of water each time. In another of these waste-preventing cisterns the pipe supplying the closet does not start from the bottom, but starts inside the cistern in the form of a siphon, which is so arranged that when the water is once started it all runs off. Another waste-preventer, of which I have a specimen here, has been recently invented by Mr. Jennings, Jr., and consists of a heavy metal cylinder with a piston inside it, the rod of which is the rod to which the handle of the closet is fixed. Upon this cylinder are two projections, one of which lifts the lever which turns on the water, and the other one which moves the valve. The piston is made so large that the cylinder adheres to it, and when the handle is pulled up the cylinder is, therefore, lifted with it, and the valve opened and the water turned on at the same time; but if the handle is held up too long the weight of the cylinder gradually overcomes its adhesion to the piston, and it falls, closing the valve of the closet and turning off the water at the same time. Thus, this water-waste preventer does not come into action at each use of the closet, but only when it is wanted. Not only water-waste preventers, but regulator valves are used in all the best forms of closets. There are, as already hinted, valves that are so constructed that they allow a certain quantity of water to pass through them whether the handle of the closet be held up or not, so that the proper quantity of water is supplied even if the handle is pulled up and let go at once. The oldest and best known of these is Underhay's regulator valve. The valve itself is, of course, worked by a lever, and the rate at which the valve is closed depends upon the rate at which the lever falls. This rate is regulated by the fall of a piston in a cylinder, the escape of air from which can be controlled by means of a small tap, so that the rate at which the lever will fall and close the valve, and, therefore, the quantity of water which will pass into the basin each time that the handle is pulled up, can be regulated to a nicety. The commonest form of this regulator is known as the bellows regulator. Other regulator valves are Tylor's and Jennings', in which, by means of simple arrangements, the rate at which the lever falls and closes the valve can be controlled. When water is delivered on the constant service at high pressure, Common's waste preventer is sometimes used. In this the requisite quantity of water is collected under pressure in an iron cylinder, the air in which is compressed by the pressure of the water from the main. When the handle of the closet is pulled up, it moves a valve, which closes the pipe from the main, and opens that leading into the basin of the closet. The compressed air in the cylinder then expands, forcing the water before it into the closet, and no more water will come in from the main until the handle is put down again, when it can only flow into the cylinder, and not into the closet. Vessels containing disinfectants or deodorants are sometimes attached to closets in such a manner that a certain portion of disinfecting or deodorizing fluid is thrown into the water in the basin each time the closet is used; but, if closets are properly constructed, this is not necessary.

We next come to the soil pipe, which conveys the waste matters from the water closet to the sewer. Soil pipes are most frequently made of lead, and they should, as a general rule, be 4 inches in diameter. Formerly, when made of lead, they were necessarily seamed pipes, as drawn lead pipes were then unknown. Consequently, there were not only soldered joints at the ends of the lengths, but a soldered seam longitudinally the whole length of the pipe. These seamed pipes should never now be used, and where found should always be taken out, as the seam gives way sooner or later, even when the pipe is placed quite vertically, and it then allows foul air to escape into the house. Pipes of drawn lead should be used, so that the only joints are at the ends of the lengths, and these can be made, and are commonly made, more durable than the pipe itself, which is not the case with the seamed joints. Iron soil pipes are sometimes used, and, indeed, are preferred in climates where there are great variations of temperature, as they expand and contract less than lead ones do. But in this climate drawn lead soil pipes are preferable, especially if they are placed, as they frequently are, inside houses, in which position I should never allow an iron one to be fixed, on account of the difficulty of being sure that air-tight joints are made; and even outside a house leaden ones are to be prefered, although more expensive, because, when iron ones are used, it is usually necessary to put lead pieces in to receive the lead pipe from the closet, to prevent a joint between lead and iron being made inside the house, and however carefully this is done, it always looks like a patched-up job. When lead pipes are placed outside houses, it is, however, necessary to have them cased to protect them from mischief or violence. The small additional expense is of little consequence, and it is better to have them cased throughout their entire length with galvanized iron. In order that they may not project too much, a chasing in the wall can be made sufficiently deep to receive about half the pipe. Stoneware pipes are also used for soil pipes, but are not to be recommended inside of houses, at any rate, on account of the numerous joints that have to be made. Occasionally, where work is "scamped," soil pipes are even made of zinc, and I have a specimen here of a D-trap made of very thin lead, with a zinc soil pipe attached. The latter has been eaten through by the foul air, as might be expected. Foul air is also capable of perforating lead soil pipes, especially if they are not ventilated, and I have here a specimen of a lead soil pipe, which was taken from under the floor of a bedroom, where it had very little fall, and which is seen to be perfectly riddled with holes, eaten through the solid lead by the foul air which accumulated in the pipe. In order to ventilate a soil pipe, it is not sufficient merely to carry a small pipe, such as an inch or even a 2-inch pipe, from the upper part of it to the top of the house, but the 4-inch soil-pipe itself should be continued (full bore) to the top of the house, and should, as a rule, project above the ridge of the roof. It may be covered simply with a perforated conical cap, not fixed on to the top of the soil pipe, but fixed so as to stand a little above it, and not to obstruct the flow of air out of it, or two or three copper wires may be fixed across the top, so as to prevent leaves from getting into it. Cowls of any kind are quite unnecessary, at any rate in the great majority of instances. Where an air inlet is made into the house sewer, the soil pipe should be carried into the latter by means of a bend—no trap of any kind being placed at the foot of it; but where this is not the case, or where it is not proposed to ventilate the house sewer by means of the soil pipe, or where the soil pipe cannot be carried above the roof, it is advisable to place a disconnecting trap of some kind at the foot of the soil pipe outside the house. In any case it is necessary that provision should be made for a free passage of air through the soil pipe. Where the vertical soil pipe is at some distance from one or more closets, so that the branch pipes from the closets to the soil pipe are, perhaps, a few feet long, it is a good plan, and sometimes necessary, to carry small ventilating pipes from below the traps of the closet, and connect them to a pipe outside the house, which should be continued up above the roof. This will prevent an accumulation of foul air in the branch pipes, and will also prevent the water passing down the main soil pipe from drawing the water out of the traps of closets beneath. It has even been proposed by Mr. Norman Shaw to disconnect the branches of the soil pipes of the closets from the main soil pipe outside the house, by making them discharge into open heads, something like the heads of the rain water pipes; and Dr. Heron has devised a plan in which part of the branch pipe is movable, and so arranged that it is only connected with the main soil pipe when the lid of the closet is open, but is removed from it by the closing of the lid; while Mr. Buchan has proposed that the branch pipe should be a channel pipe, freely open to the air along the top.

Water closets should, whenever it is possible, be separated from the house by a ventilated lobby, or, at any rate, there should be two doors with special means of ventilation for the space between them, and this leads me to speak of Mr. Saxon Snell's invention, of which I have a full-sized model here, lent by Mr. Howard, the maker. In this, by means of an arrangement called "The Duplex Lid," the closet apparatus is placed, by the closing of the lid, in a shaft which is carried up above the roof of the house. The water supply apparatus is also connected with the lid, so that the lid has to be closed in order to flush the closet.

We come now to sinks and baths.

Of sinks there are various kinds. Sometimes sinks called "slop sinks" are provided to get rid of the dirty water, although where wash-out or hopper closets are used the slops may be thrown down them. The waste pipes from slop sinks should be provided with siphon traps, and are, as a rule, connected with the soil pipes. They are, in fact, looked upon in much the same light as water closets. The other upstairs sinks, as "housemaid's sinks," and the small sinks under taps, known as draw-off sinks, must not be connected with the soil pipe or water closet apparatus. Their waste pipes should always be provided with siphon traps immediately under the sinks, in order to prevent air coming into the house through these pipes, as it is rendered foul by so doing, but at the other end these waste pipes should always be disconnected from the house sewer by discharging into a pipe with an open head like a rain water pipe, or over a gully in the area. Scullery sinks should also be disconnected from the sewer, but there is a difference of opinion as to whether or not this should be by means of a trap large enough to collect the fat from the greasy water thrown down there. If such a trap is used, it must contain a sufficient amount of cold water to cool at once the hot water from the sink that is thrown into it. But, in any case, the pipe from the sink should pass under an open grating before entering, such trap. The waste pipes from baths should also be invariably disconnected from the house sewer in the same way as those from sinks. The waste pipes of baths should be large, say two inches in diameter, not only so that they may be quickly emptied, but that the large body of water being discharged suddenly may be made to flush the house sewer. In large houses where there are laundries, this is a still more important matter. A bath should have a lead "safe" tray placed under it, the waste pipe of which must go straight through the wall of the house, and end in the open air. The disconnecting traps used in the areas for the waste pipes of sinks and baths may be either the ordinary siphon gully trap with a galvanized iron grating (the waste pipes being made to discharge either over the grating, or preferably, as a rule, through holes in the sides of the trap below the grating, but above the water in the siphon), or Mansergh's trap may be used, especially for scullery sinks or sinks on the basement floor.

To conclude. The principles that guide us in carrying out sanitary works are simple enough, but sufficient has been said in these lectures to convince every one that it is only by the minutest attention to details that we can hope to guard ourselves against the dangers that surround us, especially in the contrivances for the removal of refuse matters.

BRIDGING NAVIGABLE WATERS OF THE UNITED STATES.

Report of Gen. G. K. WARREN, in Annual Report of Chief of Engineers for 1879.

GRADES AND CURVATURES UPON BRIDGES AND APPROACHES.

Upon the distribution of the report upon bridging the Mississippi River between St. Paul, Minn., and St. Louis, Mo., some disappointment was felt that it contained no tabulated statement of the grades used upon the bridges. As a matter of fact, all that could be ascertained about the grades on the bridges was given in the description of each bridge or on the drawings of them. The bridges, excepting those of the wagon-way at St. Paul and the railway at St. Louis, were draw-bridges and the grades were level, or nearly so; a table of these grades was of little value.

Such a table, however, has been prepared for the Mississippi River and sent herewith, giving curvature also; and as it is only in high bridges that grade is important, we have taken the table of grades, &c., on the Ohio River bridges from the report of the Board of Engineers, printed in the Annual Report of the Chief of Engineers for 1871, page 425.

These two tables cover a considerable range of examples. The highest railway grade given is on the bridge at Louisville, Ky., where it reaches 1.49 feet per 100 feet.

The grade on the St. Louis Bridge is 1 foot in 100 feet, and this grade is also used at the St. Charles Bridge across the Missouri River. These grades require either special engines or low rates of speed, and there is difficulty in holding the rail to the ties to prevent its *crawling* under the action of the driving wheels of the locomotive and the vibrations of the bridge.

The question of grades has little importance whenever a draw-bridge is allowable to accommodate navigation. But whenever the bridge is for a railroad system requiring constant service for hours at a time, or where the large amount of navigation would require the drawers of a draw-bridge to remain open for continuous passage of vessels for many hours at a time, the accommodation of both means of transportation requires high bridges.

On high bridges where the railroad business is large and considerable speed of transit is required, the grade should be kept as low as possible with due regard to economy of construction. Where, in such cases, high grades are used, the strength, and rigidity must be increased with the grade, or special locomotives or stationary power should be employed. The advantages which this latter method presents will permit of much higher grades than can be allowed by traction engines.

TABLE GIVING MAXIMUM OF GRADE AND CURVATURE ON BRIDGES AND APPROACHES ON THE MISSISSIPPI RIVER.*

[Data taken from Warren's Report on Bridging the Mississippi River. Annual Report Chief of Engineeers for 1878, Part II, pp. 900–1125.]

Name of Bridge.	Grade per 100 ft.		On Bridge or Approach.	Curvature.		On Bridge or Approach.
	Right Bank.	Left Bank.		Right Bank.	Left Bank.	
	Feet.	*Feet.*				
St. Paul Railway	0.5	0	Approach ..	4° curve	5° curve	Approach.
St. Paul Highway	5.0	0	Bridge.....	Tangent	Tangent	
Hastings Railway..........	0.3	0	Approach ..	2°	Tangent	Approach.
Winona Railway	1.0	08.	" ..	10°	Tangent	"
" "	....	05.	Bridge.....	....	....	
La Crosse Railway.........	0.4	05.	Approach ..	2°	6°	Approach.
Prairie du Chien Railway. (This is a ponton bridge with two sets of approaches—one for high stages, the other for low.)						
Dubuque Railway	0	0	....	4°	9°	Approaches.
Clinton Railway...........	0	0	....	0	0	
Rock Island Rail and Highway	....	....	....	$3\frac{1}{3}$°	Tangent	Approach.
Keokuk Rail and Highway.	0	0.8	....	$6\frac{3}{4}$°	"	"
Quincy Railway...........	0	0	....	Tangent	4°	"
Hannibal Rail and Highway	0	0	....	$9\frac{1}{2}$°	6°	"
Louisiana Railway.........	0	0	....	8°	Tangent	"

* The Saint Paul Highway Bridge is the only high Bridge on the Mississippi from St. Louis to Fort Snelling. The channel-span is sixty-three feet above high water and eighty-five feet above low water. The others are swing draw-bridges, about ten feet above high water.

The following is a tabular statement of the principal features of the bridges over the Ohio, together with the cost of each bridge as far as ascertained. Nothing but the actual cost between abutments has been taken, all land damages and connections with main track having been excluded.

Name of Bridge.	Length of Approach from right bank.	Length of Approach from left bank.	Total Length, including approaches.	Maximum Grade per mile (equated.)	Maximum curvature.	Above Low Water.	Above Highest Water.	Maximum Local Rise.	Width at Low Water of channel openings on axis of bridge.	Cost.
	ft.	ft.	ft.		° ′	ft.	ft.	ft.	ft.	
Steubenville Railroad..	......	......	1,895.4	......	......	90	45	45	303¼	$1,000,000
Wheeling (Highway)...	......	......	980	253	......	91½	48	43½	980	161,594
Bridgeport (Highway)..	......	......	638	......	......	53	9½	43½	212	68,500
Bellaire Railroad	1,490	864	4,001½	60.3	5	90	40	50	{ 322 { 220	Unfinished
Parkersburg Railroad..	726	1,994	4,262	59.3	4.20	90	40	50	{ 326½ { 326½	1,223,550
*Newport & Cincinnati Railroad, as commenced	950	230	2,961.5	57.2	10	71½	9	62½	400	*820,394
Newport and Cincinnati Railroad, as altered..	2,400	1,680	5,861.5	66.0	10	100	37½	62½	400	†1,109,089
Covington & Cincinnati (Highway)..........	......	....	1,619	283	......	103	40½	62½	1,005	1,480,000
Louisville Railroad....	......	....	5,218⅔	79.1	......	96½	45½	51	{ 380 { 352½	1,615,120
Paducah Railroad......	......	......	....	......	......	.....	....	52¼	....	Not begun

NOTE.—The lengths of earthen embankments are not included in the above.

G. K. WARREN,

Lieut. Col. Engineers and Brevt. Maj. Gen.

* This bridge was designed and nearly completed with the following grades and alignment: commencing at a point 750 from the abutment on the Newport side, the grade was 0.2393 foot per 100 to the end of the first span, or 882 feet, then level over seven spans, 1457.4 feet; then a grade of 0.465 foot per 100 on the last two spans, and 100 feet of the approach on a curve of 609 feet radius; then 0.8 foot to the 100 for 450 feet on a curve of 573 feet radius; then 0.8 per 100 on a tangent until the main line is reached. The Board of Engineers reported that the bridge as being built would prove a serious obstruction to navigation and that it should be raised 28½ feet to give 100 feet headway at lowest water, and 37¼ feet at highest water. An estimate was made for doing this by lengthening the approaches on the same alignment. In this modification the maximum grade adopted for the approaches was 66 feet per mile, on tangents, for the reason that this was the ruling grade of the railroad on the Kentucky side, which had grades of 60 feet to the mile on 6° curves.

The raising of the bridge as recommended by the Board was ordered by Congress. It is not known what the new grades are as reconstructed, but they are in excess of those in the engineering board's plan, the height being the same while the approaches were not lengthened or the alignment changed.

† Estimated.

THE NATURE OF ELECTRICITY.*

From "Nature."

ON surveying the wide sea upon which the numerous and varied practical applications of electricity are launched for the subject of this evening's address, I have been puzzled to steer a course that shall avoid the dazzling shoals of theory on the one hand, and the dry hard rocks of practice on the other, Hypothesis is a veritable Scylla that captivates the imagination and often sends the visionary to destruction, while practice alone is a hard-hearted Charybdis that lures the matter-of-fact practical man to folly and expense. Practice must be tempered with theory to utilize advantageously the great forces of nature, and theory itself must be based on practice, or on facts, to be comprehensive and acceptable. Hence success is the offspring of the marriage of practice and theory, and, therefore, as the two are so intimately connected, I have determined to steer a middle course to-night to survey the progress of each in our profession, and to show their mutual relationship.

* Abstract of the Inaugural Address to the Society of Telegraph Engineers, by Mr. William Henry Preece (President), delivered January 28, 1880. Revised by the author.

What is theory? It is an explanation of the hidden cause of certain effects that are evident to the senses. It is an effort of the imagination to account for operations that are in themselves invisible and insensible, but which result in facts that are observable and known. Thus, the movements of all those bright bodies by which

> "The floor of heaven
> Is thick inlaid with patines of bright gold,"

are explained by the theory of gravity. Their appearance, vagaries, and beauties are accounted for by the undulatory theory of light. The warmth that the monarch of them all shed upon this earth countless ages ago, and that is now restored to us in our household fires, is explicable on the molecular theory of heat. The constitution of matter and its various states of solid, liquid, and gas, are completely explained by the atomic theory of Democritus and Dalton, and the modern kinetic theory of gases.

It is impossible for a practical man who has devoted more than a quarter of a century to the application of electricity to useful purposes, to avoid devoting much contemplation to the nature of the agent which he has to make use of. Is there a member of this society who has not striven to peer into the region of the unknown, who has not speculated on the power he uses, or who has not formed some conception in his mind of the nature of electricity? Yet it is remarkable that the answer to the question, What is electricity? cannot even now be given with authority. Faraday, our great apostle, whose researches should be every electrician's bible, declined to venture an answer, nor did he ever directly formulate his ideas on the subject, though his publications indicate pretty clearly, and with no uncertain sound, what they were. Clerk-Maxwell, who, while he overthrew all existing theories, failed to supply their place before he was so untimely removed from us. Sir William Thomson, in his published papers, always carefully eschews the consideration of any physical theory of electricity. The French electricians simply use the one-fluid theory as a convenience of language, while the Germans, as a rule, employ the two-fluid theory merely for mathematical purposes. Hence there is no recognized theory of electricity. Some maintain with Du Fay or with Franklin, that it is a form of matter —a substance; others, following Faraday and Grove, consider it a form of force—a motion—like heat and light. It must be either one or the other. There is no other category in which to class it. If it is not a form of matter it must be a form of force. The question I propose to discuss is, therefore, Is electricity a form of matter, or is it a form of force?

In discussing such a vexed question it is necessary to be very precise in language to avoid any misconception of my meaning, therefore I will define both matter and force in the sense in which I use those terms. *Matter* is that which can be perceived by the senses, or can be acted upon by force. It is characterized by weight, inertia, and elasticity. *Force* is that which produces, or tends to produce, the motion of matter. It may be pressure, tension, attraction, repulsion, or anything capable of causing alteration in the natural state of rest or of existing motion of matter.

Matter is found in either the solid, liquid, gaseous or ultra-gaseous state, and it occupies space. It consists of molecules and atoms. The *atom* is the smallest indivisible part of an element, and a group of atoms of the same or of different elements forms the *molecule*, which has a definite magnitude and is unalterable in form for each substance. The *mass* of a substance is the aggregate of the molecules of which it is composed. There is no generation or destruction of atoms. The indestructibility of matter is a fixed law in nature. The size of the molecule is approximately known. Sir William Thomson says: "If we conceive a sphere of water as large as a pea to be magnified to the size of the earth, each molecule being magnified to the same extent, the magnified structure would be coarser-grained than a heap of small lead shot, but less coarse-grained than a heap of cricket balls." Fifty million molecules ranged in single file would occupy an inch. They are highly elastic, and unless interfered with would move with constant velocity in straight lines. When they can move about freely without interfering with each other's proceedings, we have the ultra-gaseous state of

Crookes, a state found only in very high vacua and under certain adventitious circumstances. When they collide and impinge on each other according to the law of the impact of elastic bodies, interfering with each other's path, we have *gases* as we know them; when their mean free path is so reduced as to bring them within the sphere of mutual attraction, without too narrowly restricting their play, we have *liquids;* when the attraction becomes cohesion and the motion of the molecule is confined to its own sphere, we have *solids.* The number of molecules in a given volume of gas is known, and their velocity calculated. In hydrogen the velocity at 0° Cent. is 6,097 feet per second, the number being 10^{28} per cubic inch. The mean free path of a molecule in air at ordinary pressure is the ten-thousandth part of a millimeter. Besides their constant motion in straight lines the molecules may be set in vibration, rotation, or any other kind of relative motion whatever.

This is the atomic theory of matter born in the brain of Democritis, "the laughing philosopher," 2,300 years ago; preached by Epicurus in Athens, and taught by Lucretius in Rome before the Christian era; lying dormant for eighteen centuries, until it was formulated by Dalton in the last century, and removed from the region of pure speculation by Joule, Clausius, Clerk-Maxwell, and Crookes during our days.

The definition of force shows us that whatever changes or tends to change the motion of matter (or of the molecules of which it is composed), by altering either its direction or its magnitude, is a form of force. Thus gravity is a form of force, for it attracts all matter to the center of the earth, and it is measured by the rate per second at which a body acquires a velocity in this direction when falling freely at a given spot. Heat is a form of force, for it throws the molecules of matter into violent vibration, or it increases the velocity of their motion in straight lines, which thus becomes the measure of its heat or its *temperature.* Light is a form of force, for it is produced by the undulation of the molecules of matter, and it is transmitted by the undulations of that medium called Ether, which fills all space.

When we take a given free mass and impress upon it a given force, we throw that mass into motion; for instance, when we fire a loaded cannon, we have imparted to the ball "*energy*," and in virtue of the motion of the ball, this energy is called "*kinetic.*" Again, if we lift the ball to a certain height above the earth's surface—say to the top of a tower—and let it remain there, we have again imparted to it "energy," but this time it is called "*potential*," for it is dormant or resting. In each case the energy possessed by the ball is the exact equivalent of the work done upon it, that is, of the force impressed and the distance through which it has acted. The motion of the ball is readily transferred to the motion of the individual molecules of the ball. When, in the first case adduced, the ball strikes the side of a ship or a target, its kinetic energy is thus converted into light and heat, which is molecular motion; or, in the second case, when it is allowed to fall, its potential energy is converted into kinetic energy, which again, on coming in contact with the ground, is converted into molecular motion or heat. Energy is always either potential or kinetic, and one of the most remarkable generalizations of modern days is the grand principle of the conservation of energy, which implies that the total energy of the universe is a quantity which can neither be increased nor diminished, though it may be transformed into any of the forms of which energy is susceptible. Energy is therefore as indestructible as matter. All the recent advances in the science of heat have been due to the discovery of this principle, and its application to electricity has gone far to remove that science from the hypothetical state in which it has existed so long.

My purpose is to contend that electricity is not a form of matter but a form of force, and that all its effects are evident to us in one or other of the several forms of energy characterized by the motions of molecules or of mass.

It is interesting to trace the historical growth of theories. The uncultivated human intellect cannot soar above its own limited sphere of childish observation. Whatever is mysterious and incomprehensible in nature is attributed to that which is equally mysterious and incomprehensible. Life has ever been of this character, and heat, magnetism, electricity, and many other unaccountable physical phenomena, have each in their turn been supposed to be causes of life. Even now there are those who would attribute exceptional and peculiar phenomena to spiritual agencies.

Heat was thought by the Greeks to be an animal that bit. It was then for many centuries thought to be a fluid which, entering into bodies, like mercury, made them swell, and this idea existed until this generation, when Rumford showed it to be a kind of motion, and Joule made it a quantitative form of energy.

Thales of Miletus thought that the magnet was endowed with a sort of immaterial spirit, and to possess a species of animation. The Greeks knew also that rubbed amber attracted bits of straw, and supposed it to be endowed with life. Even Boyle, as late as 1675, imagined it to emit a sort of glutinous effluvium which laid hold of small bodies and pulled them towards the excited body. Du Fay in 1733 conceived the double fluid theory, and Franklin in 1747 invented the single fluid theory. Cavendish in 1771 supplied some of the deficiencies of Franklin's theory, but it was Faraday who first exploded the fluid notion and originated the molecular theory of electricity, while Grove boldly classed electricity with light and heat as correlated forces and mere modes of motion.

Light was thought by the Platonists to be the consequence of something emitted from the eye meeting with certain emanations from the surface of things, but no theory of light properly so called was attempted until Newton produced his celebrated corpuscular theory in 1670, which has lasted until the present day. Even as late as 1816 Faraday himself said: "The conclusion that is now generally received appears to be, that light consists of minute atoms of matter of an octahedral form, possessing polarity, and varying in size or in velocity."* Although Huygens in Newton's own time conceived the undulatory theory, the superior authority of the great English philosopher overshadowed the lesser light, and it was not until Young and Fresnel at the commencement of this century took the matter up, that the present theory of light took firm root. Thus we see that all these sciences have passed through the same stages of mystery and fancy, and it is only within the present generation that they have emerged from the mythical to the natural, from mere hypothesis to true theory. *Hypothesis* is an imaginary explanation of the cause of certain phenomena which remains to be shown probable or to be proved true. *Theory* is the supposition when it has been shown to be highly probable and all known facts are in agreement with its truth.

A theory, therefore, to be valid and true, must agree with every observed fact; it must not conflict with natural laws; it must suggest new experience, and it should lead to further developments. A theory is absurd if it supposes an agent to act in a manner unknown in all other cases. The fluid theories of electricity are merely descriptive, they do not agree with every observed fact; they have never prompted the invention of a single new experiment or led to any development. They suppose an agent unknown in other cases and opposed to natural laws. Incomplete theories die a natural death: thus Descartes' vortices, Newton's corpuscular theory of light, the fluid theory of heat, Stahl's phlogiston, Nature abhorring a vacuum, have all disappeared, while complete theories, such as that of gravity, the laws of motion, the conservation of energy, the undulatory theory of light, not only remain, but suggest new fields of inquiry, open out fresh pastures, carry truth and conviction with them, and have led to the most wonderful predictions. The fluid theories of electricity are certainly incomplete, and they deserve a speedy interment. We have to assume the existence of two substances of opposite qualities which mutually annihilate each other on combination—a self-evident absurdity, for the conception of matter involves indestructibility. Franklin imagined his one fluid to be an element of glass; remove electricity, and glass would lose its virtues and properties, and thus glass was to give out its electricity for ever and a day, without loss of weight or sensible diminution. It was to be devoid of dimensions, inertia, weight, and elasticity, and is therefore outside the pale of our definition.

* "Life," vol. I, p. 216.

Electricity is therefore not a form of matter. Hence, according to our reasoning, it must be a form of force.

But can we not prove that it is a form of force? Certainly.

Let us first argue from analogy. We know that sound, heat, and light are modes of motion; in what respect does electricity agree with these forms of force?

The fundamental law of electro-statics is that two bodies charged with opposite electricities attract each other with a force dependent on the square of the distance separating them. Whatever influence or power spreads from a point and expands uniformly through space varies in intensity as the square of the distance for the area over which it is spread increases as the square of the radius. This is the case with gravity, light, sound and heat, which are known forms of force. It is also the case with electricity and magnetism, which ought therefore to be similar forms of force.

If we regard the velocity of transmission of certain electrical disturbances through space we have every reason to believe that it is the same as that of radiant heat and light. In 1859 two observers in different parts of the country (Messrs. Carrington and Hodgson) saw simultaneously a bright spot break out on the face of the sun, whose duration was only five minutes. Exactly at this time the magnetic needles at Kew were jerked, and the telegraph wires all over the world were disturbed. Telegraphists were shocked, and an apparatus in Norway was set on fire. Auroras followed, and all the effects of powerful magnetic storms. Moreover, the periods of sun spots, earth currents and magnetic storms follow the same cycle of about eleven years. Dr. Hopkinson has shown that this electric disturbance through space is as mechanical as its action through short distances, and is therefore identical with the ordinary strains of elastic matter subject to distortion by mechanical force. But Clerk-Maxwell has gone beyond this, and has shown that the velocity of light is identical with that of the propagation of electrical disturbances through space as well as through air and other transparent media. Hence, as light is admitted to be a mode of motion identical with radiant heat, electricity must be of the same category.

There is such a remarkable analogy between the conductivity of the different metals for heat and for electricity—indeed, there is every reason to believe that if the metals were pure, the order and ratio of conductivity would be identical—that it is impossible to resist the conclusion that the mode of transmission in each case is the same. Mr. Chandler Roberts, who, using Prof. Hughes' beautiful induction balance, showed, by experiments on a comprehensive series of alloys, that the curves indicating the induction-balance effect closely resemble their curves of electrical resistance. He was also able to demonstrate that the induction-balance curve of the copper-tin alloys is almost identical with the curve of the conductivity of heat—a conclusion of much interest; and he pointed out that we might look with confidence to being able to ascertain, by the aid of the induction-balance, whether the relation between the conductivity of heat and electricity is really as simple as it has hitherto been supposed to be. Moreover, when a wire conveys a current of electricity it is warmed, as the strength of current is increased it is heated and eventually rendered incandescent. The ultimate form which every electric current takes is heat. The wire of every telegraph is warmed in proportion to the currents it transmits. Joule showed that when this heat is produced by a current generated in a battery by chemical force, its amount is exactly equivalent to that which would have been evolved by the direct combination of the atoms. The conducting power of all bodies is affected by heat, and some even, like selenium, by light. Hence, as we know that in the case of heat and light conduction is molecular vibration, we reasonably conclude that it is the same with electricity. In fact, it is impossible to account for these phenomena except on the assumption of the motion of the molecules.

The magnificent researches of Dr. Warren de la Rue and Dr. Hugo Müller on the electric discharge with the 11,000 cells of chloride of silvery battery that the former philosopher has provided himself with in his celebrated laboratory, have shown indisputably that the discharge in air or in gases under various pressures is a function of the molecules filling the space through which the discharge occurs. In fact, the resistance of the discharge between parallel flat surfaces is as the number of molecules intervening between them ; and they show that during electrical discharge in a gas there is a sudden and considerable pressure produced by a projection of the molecules against the sides of the containing vessel distinct from that caused by heat, and unquestionably due to the molecular action of electrification. The long-continued and patient researches which these eminent physicists are carrying out prove beyond doubt that electrical discharge is simply molecular disturbance. In reality, the fact that no discharge occurs through a perfect vacuum is a crucial proof of the molecular theory.

Some recent very remarkable researches of M. Planté with his rheo-static machine* have shown that fine wires conveying powerful currents are wrinkled up into well-defined regular nodes, that these effects are accompanied by a peculiar crackling, and that the wire itself becomes brittle, giving clear indication of the vibratory motion of the molecules. He gives as the result of his inquiry, that electrical transmission is the result of a series of very rapid vibration of the more or less elastic matter which it traverses, and he points out certain analogies between electric motion and sonorous vibrations. This view is supported by the researches of Professors Ayrton and Perry† on the viscosity of dielectrics.

Prof. Challis, of Cambridge, has extended this view so far as to embrace magnetism, electricity, light, heat, and gravity in one category of physical force, and to assert that they all result from motions and pressures of a uniform elastic fluid medium pervading all space not occupied by atoms. His views, however, have not received much attention, for they are not based on the foundation of any new facts, and they are utterly subversive of many cherished principles deeply rooted in the scientific mind. It is to be observed, however, that he regards electricity as a form of force.

Mr. Crookes, in his recent beautiful experimental researches into molecular physics in high vacua, has still more conclusively proved the connection that exists between electrical action and molecular motion. In fact, his experiments are so brilliant, his expositions so lucid, that one can fancy one sees with the eye of the body that peculiar play of the molecules which can be evident only to the eye of the mind. Not only has Mr. Crookes established as a physical fact the kinetic theory of gases and the molecular constitution of matter, but he has indicated the existence of a fourth state of matter where the molecules fly about without mutual let or hindrance. He has also led us to doubt the truth of the generally received opinion that an electric current flows from the positive to the negative electrode. It would appear from his investigations that the reverse is the case. Be that as it may, he has added one story to the structure of the molecular theory of electricity.

The criterion of a good theory is, however, its power of prediction. A false theory has never led to prevision. Neither the corpuscular theory of light, nor the fluid theories of heat and electricity, ever led to the prediction of something of which eyes had not seen nor ears heard. The triumphs of prediction in astronomy, sound, light, and heat are innumerable. Faraday predicted the effect of induction in lowering the velocity of currents of electricity and the action of magnetism on a ray of light. Sir William Thomson predicted that a current in passing from a hot to a cold part of a copper bar would heat the point of contact, while in an iron bar it cools it. Peltier predicted the cooling effect of currents on the junctions of thermo-electric pairs.

But the true identity of these physical effects is conclusively shown by their quantitative character and by their adhesion to the law of the conservation of energy. Take the case of the electric light: the consumption of coal in a furnace generates steam, the steam works an engine, the engine rotates a coil of wire in a magnetic field, the motion of the coil in this field induces currents of electricity in the wire, these currents of electricity produce an arc, and thereby heat and light. The energy of the coal is transformed into heat and

* *Comptes Rendus* LXXXIX, pp. 76—80, 1879.

† *Proc. Roy. Soc.* pp. 7—8, 1878.

light through the intermediate agency of electricity. Is it possible to conceive that this intermediate agency is anything but a form of energy? Take the case of the Bell telephone: the energy of the voice produces the energy of sonorous vibration in the air, the vibrations of the air cause the vibrations of the iron disk, the vibrations of the disk vary the magnetism of the magnetic field, this produces currents of electricity in a small coil in this field which vary the magnetism of the distant magnet, which in its turn throws its disk armature into vibration, and thereby repeats at the distant station the sonorous vibrations of the air, and thus reproduces the energy of the voice. A tuning fork comes to rest sooner in front of a telephone than when it is allowed to vibrate freely in air. Here we have the energy of the fork passing through the several stages indicated above, and ultimately coming out in its original form. The energy of sonorous vibrations at the distant station is that lost by the vibrating tuning fork.

Is it possible to assume that in this cycle of changes energy has been transformed into matter and matter again formed into energy? It is impossible and absurd. Clerk-Maxwell said:—"When the appearance of one thing is strictly connected with the disappearance of another, so that the amount which exists of the one thing depends on and can be calculated from the amount of the other which has disappeared, we conclude that the one has been formed at the expense of the other, and that they are both forms of the same thing."

Would it be possible to light the streets of New York by the energy of the falling water at Niagara, as has been suggested by our Past President, Dr. Siemens, if the cycle of changes from the one spot to the other were not all different forms of this same energy? Would it be possible to plow a field a mile away from the source of motive power of the transmitting medium if the electric currents were not forms of the same power? Electricity in its effects is and must be a form of energy.

The final stage into which any physical theory grows is that in which every action can be expressed in mathematical language, where every phenomenon is calculated upon an absolute physical basis, and where we can foretell exactly what will occur under any possible emergency. This is the present condition of the science of electricity. We can calculate exactly how much steam power is required to generate a given current to produce a given light. We can tell precisely what dimensions of cable are necessary to give a certain number of words per minute on the other side of the globe. If a fault develop itself in a long cable through the gastronomic propensities of a thoughtless young teredo, we can calculate to within a few fathoms the locality of his edacious depredation.

Clerk-Maxwell,* in his classical work on electricity, has used a somewhat curious argumen tto show that electricity is not, like heat, a form of energy. He says that energy is produced by the multiplication of "electricity" and "potential," and that it is impossible that electricity and energy should be quantities of the same category, for electricity is only one of the factors of energy, the other factor being "potential." But this does not militate in any way against the force of the argument, for in nature we can no more do so that we can separate heat and temperature. Energy usually appears as the product of two factors, and it is the equivalent of the work done. Thus *Potential energy* is the product of mass and gravitation acting through a distance. *Kinetic energy* is the product of mass and the half square of velocity. The energy of fluids is the product of volume and pressure. The energy of heat is made up of heat and temperature, and the energy of electricity is the product of electricity and potential. Hence it is that electricity, *per se*, may be said to be a form of force, while all its effects as known to us are forms of energy. Force alone cannot produce energy; it must be force and something else. Force is the power of producing energy, and it must have something on which to produce it. Hence matter is always present; and thus, though heat, light and electricity are forms of motion, they are in reality properties of matter from which they are inseparable. They are evident to us through the play of the molecules of

* Vol. I, p. 30.

matter, and thus are properly called molecular forces.

Earth currents have been a favorite subject of inquiry of mine for many years. I have always entertained the idea that they are directly due to the action of the sun. Some disturbance in the sun causes, by induction, a variation in the distribution of the lines of potential on the earth's surface, and produces the conditions required for these currents. I have many facts to support this hypothesis, but I want more to confirm it. Profs. Ayrton and Perry have developed a theory of terrestrial magnetism based on the assumption that the earth is a highly electrified sphere, which not only coincides well with facts, but which tends greatly to support my views. I want observers to record the times of daily maxima and minima. I want them especially to note during those periods of unusual disturbance the direction of the circuits which are *not* affected, for they would give the direction of the lines of equi-potential. This not only offers a useful field of observation, but its failure or success will illustrate the modern method of scientific research, when the brain suggests to the hand and the eye what they have to do, and what they have to look for.

THE PANAMA CANAL.

By Captain BEDFORD PIM, R. N., M. P.

From "Journal of the Society of Arts."

PART II.

CENTRAL AMERICA

In defining the boundaries of Central America, I shall not restrict myself to the narrowest part, commonly called the Isthmus of Panama, but include the entire country, from the first narrowing of the lands of North America at the Isthmus of Tehuantepec, between the 16th and 18th parallel of north latitude, and 94th meridian of west longitudes, to its expansion into South America at Darien in the 7th parallel of north latitude and 77th west meridian. In this definition I have been guided, not by political divisions, but by what appear to be the strict geographical limits of the center of the New World.

Central America, then, lies between the 7th and 18th parallels of north latitude, and the 74th and 94th of west longitude; its least breadth from sea to sea is 27 miles at lat. 9° N., long. 79° W. The extent of its coast line, counting all its sinuosities, is about 3,000 miles, its length from end to end about 1,350 miles, its direction north-west and south-east, and its area about 300,000 square miles, or about the size of Great Britain and France put together.

SUEZ AND PANAMA.

It is hardly possible to conceive anything more widely different than the nature of the connecting links joining together the continents of the Old and New Worlds. In the former we have a broad, flat, low expanse of parched and arid country, rather more than 70 miles across—a complete desert; in the latter, a mountainous surface, and very irregular coast line, extending over many hundreds of miles, teeming with animal and vegetable life, and only, at its narrowest part, about half the width of the Old World Isthmus. There is another striking dissimilarity—the one possesses the earliest records of the human race in readable hieroglyphics, and is crowded with historical associations of the deepest interest to mankind, whilst the other is a comparatively modern addition to the history of the world, with writings still an enigma to science.

STATES AND PROVINCES.

There are so many well-written accounts of Central America, from its conquest and partial occupation (the first European settlement was formed by Columbus in 1502), until the final expulsion of the Spaniards, between the years 1820 and 1823, that it seems superfluous to enter upon its earlier history; and I shall, therefore, simply confine myself to a brief notice of the various States and dependencies.

Within the limits I have defined as the natural boundaries of the center of the New World are included two provinces of New Granada (Panama and Veraguas, commonly called the Isthmus of Panama), two of Mexico (Yucatan and Chiapas), an English colony (Belize, or British Honduras), five republics (Costa Rica, San Salvador, Honduras, and the Bay Islands, Guatemala, and Nicaragua), and the Indian kingdom of Mosquito. The five republics number altogether forty five districts, each with a capital, and 253 towns and villages, exclusive of capitals. Costa Rica has 8 districts; San Salvador, 4; Honduras, 12; Guatemala, 13; and Nicaragua, 8; making in all, 45, while the population living within this area is not less than two million souls, or only 7 to the square mile of 640 acres, thus leaving an ample field for future development.

TRANSIT.

I shall now mention the various schemes of transit by canal, which have from time to time been proposed at and between Tehuantepec and Darien.

In little more than ten years after the first settlement was formed by Columbus, the Isthmus of Panama was successfully crossed by Vasco Nunez de Balboa (September, 1513), who, rushing up to his breast in the water of the Pacific, took possession of that mighty ocean in the name of his master, the King of Spain. From that period, the outline of the Pacific coast, both to the north and south, has been rapidly delineated on the charts, and a glance is sufficient to show how narrow a strip of land intervened at more than one point between the oceans. Then arose the desire to find a practicable route from sea to sea; and as commerce and colonization increased, doubtless every effort was made by the early conquerors and their followers to discover such an opening, but entirely without success as regards a water passage. In the town library at Nurembergh is preserved a globe made by John Schöner in 1520, on which a passage through the Isthmus of Darien is carefully delineated. Owing to the extraordiuary jealousy of the mother country, but little has ever transpired as to the nature of the explorations made with a view to transit by the early conquerors; and the first authentic account of the nature of the overland passage from sea to sea was obtained from the buccaneers, from whom that most remarkable man, William Paterson, one of the founders of the Bank of England, gleaned the information which enabled him to propound a project which was the grandest conception, as it was the greatest national misfortune, of the seventeenth century. Paterson's noble project of opening a "highway of nations" was basely and treacherously ruined, and the idea was not revived until after the Spanish American colonies had thrown off the yoke of the mother country; then, indeed, a host of plans were formed for joining the two oceans.

TEHUANTEPEC.

Fernando Cortez was the first who gave his earnest attention to the search for a practicable route from sea to sea. In his admirable letter to the King of Spain, this passage occurs: "It is the thing above all others in this world I am desirous of meeting with, on account of the immense utility which I am convinced would result from it." Cortez appears to have concentrated his attention upon the isthmus at Tehuantepec, and so great was his confidence in the belief that at this part of Central America the problem would be solved, that he selected the lands in the vicinity as his portion of the conquered country.

After the death of Cortez, the idea of forming a passage from sea to sea, across the Isthmus of Tehuantepec, appears to have been abandoned; indeed, the jealousy and bigotry of the conquerers seems to have caused a reaction in favor of closing every avenue of approach to the New World, instead of opening new roads through it. The learned divine, P. d'Acosta, writing in 1588, says: "I am of opinion that no human power would be sufficient to cut through the strong and impenetrable bounds which God has put between the two oceans, of mountains and iron rocks, which can stand the fury of the raging seas; and, if ever possible, it would appear to me very just to fear the vengeance of heaven for attempting to improve the works which the Creator, in His Almighty will and providence, ordered from the creation of the world." It is not a little curious that exactly 200 years later (1788) another divine, the Cura of Darien, secured to himself the honor of making a water communication from sea to sea, at the southern extremity of Central America, by a shallow canal from the water of the Atrato to the head waters of the Nipipi, which empties itself into the Pacific. The ruins of the canal could be plainly traced some 30 years ago, when I was engaged in the survey of the Bay of Panama.

In 1814, the Spanish Cortes authorized the formation of a canal across the Isthmus of Tehuantepec in preference to Nicaragua or Panama. In 1842, the Provisional President of Mexico, Santa Anna, granted to Don José de Garay, the exclusive privilege of using steam locomotive power for transit across the isthmus, and that gentleman caused the most elaborate surveys of the route to be made; but the length of the line, the poorness of the ports at each extremity, and the distracted state of the country, combined to deter capitalists from embarking on such an undertaking, and consequently nothing has been attempted. Dampier, Don Augustin Cramer, and the great Baron von Humboldt, have at various times spoken in favorable terms of this route. The latter writes: "We cannot doubt that this point of the globe deserves no less attention than the Lake of Nicaragua."

A canal across the Isthmus of Tehuantepec would be at least 140 miles in length, the summit to overcome would be 656 feet, while the estimated cost reached nearly four millions sterling, and that without including the formation of harbors on either side; the actual sea approaches being mere roadsteads. The grants for opening a canal across Tehuantepec (1842) was the first concession of any Spanish American Republic for crossing the country.

NICARAGUA.

The Nicaraguan project has been upheld by many first-rate men, Baily, Stephens, Kelly, and others. In 1830, a company was formed in Holland, under the patronage of the King, for making the canal, but the disturbances in that country broke up the company. Again, in 1835, the project was brought before the Government of the United States, and a resolution of the Senate was passed in favor of it; but the agent sent by General Jackson, then President, to arrange with the Nicaraguan authorities, died on the road, and the matter was allowed to drop. No one, however, has taken so warm an interest in the subject as the late Emperor of the French. It appears that Don Francisco Castillon, envoy to the Court of France, put himself, in 1840, in communication with Prince Louis N. Bonaparte, at that time a prisoner at Ham, and proposed to him, in the name of the Nicaraguan Government, to take upon himself exclusively the construction of the proposed canal. After his escape from Ham and safe arrival in London, he devoted a considerable amount of time and study to it, and not only wrote a most able pamphlet, but publicly advocated the project at the Institution of Civil Engineers, in 1847.

I have made careful extracts from the valuable notes of the Emperor Napoleon III., and have no doubt that a reproduction of those extracts in this place will be agreeable to our members, and prove an addition to the pages of our *Journal* of no mean value, not only to its readers, but to the advantage of the Society itself. The extracts will be found further on.

In the years 1837 and 1838, a survey was made Mr. John Baily, lieutenant in the Royal Marines, at the request and under the authority of General Morazan, then President of the Central American Republic, for the purpose of ascertaining the practicability of forming a canal from the port of San Juan del Sur, on the Pacific Ocean, in lat. 11° 15′ N., long. 86° 1′ W. by the Lake of Nicaragua and the River San Juan, to the Atlantic.

The port of San Juan del Sur is narrow at the entrance, but widens within the harbor; it is surrounded by high land except from west-south-west to west-by-south; the depth of water at the entrance is three-fathoms, and its width 1,100 yards. Ships can go up for about half a mile, but as the winds often blow with great violence from the north and north-east, there is sometimes considerable difficulty in making the anchorage.

From this port Mr. Baily took a line of levels, not in a direct course, but diverging, so as to pass between the hills at the lowest point, when it could be done without widely deviating from a straight line, and in many places he passed through ravines of from 30 to 120 feet in depth. Mr. Baily found the ground rise, with a gradual acclivity, from the beach to the distance of 5,880 yards, where it attained a height of 284 feet, then for 904 yards it rose rapidly to the summit 615 feet above the level of the ocean.

The ground then descended rapidlly, and in a distance of 8,664 yards, the elevation was reduced 295 feet, whence it gradually sloped with but slight interruptions for a further distance of 6,168 yards, where it joined the River Lajas, along which it ran for 6,792 yards, and afterwards discharged itself into the Lake of Nicaragua. The surface of that lake was 128 feet 3 inches above the level of the sea; the whole distance from the South Sea to the lake, by Mr. Baily's track, being 28,408 yards, and his mean course N. 33° E.

The dimensions of the Lake of Nicaragua are variously given by different writers; but Mr. Baily seems to have taken some pains to ascertain them exactly, and he states the length to be 95 miles, the breadth in its widest part to be about 53 miles, and the average depth of water, according to his soundings, 15 fathoms. These dimensions agree with the map of Don Felipe Bouza.

The length of the river San Juan, with all its surroundings, from the lake to Grey Town, is 119 miles, with a fall of 107½ feet. There are four rapids, viz., Machula, Castillo Viejo, El Nuco, and del Toro, extending over about six miles, with broken water running over a rocky bottom. The San Juan is fed by many tributaries, the largest of which are San Carlos and Serapique, taking their rise in Costa Rica. The volume of water in the San Juan varies of course in different seasons; at the commencement of June, the lowest stage, about 12,000 cubic feet per second passed from the lake. The greatest rise in the lake ever known was six feet. At high lake, about October, there is probably about 40,000 and 50,000 cubic feet per second, divided at the delta of the river, of which about three-fourths pass out by the Colorado branch, and the remainder by the San Juan.

The whole length of the canal, from the Lake of Nicaragua to the Pacific, is fifteen miles and two-thirds. According to the plan, in the first eight miles, only one lock is necessary; in the next mile, sixty-four feet of lockage are required; in the next three miles there are about two miles of deep cutting, and one mile of tunnel, and then a descent of 200 feet in three miles by lockage to the Pacific.

Thus far of the canal across the isthmus.

The Lake of Nicaragua is navigable for ships of the largest class down to the mouth of the River San Juan (where it quits the lake). This river has a fall of one foot and six-sevenths per mile to the Atlantic. If the bed of the river cannot be cleared out, a communication can be made either by lock or dam, or by a canal along the bank of the river. The latter would be more expensive, but on account of the heavy floods of the rainy season it is preferable.

The total length of the canal from sea to sea would be little short of 200 miles, viz., 15½ from the Pacific to the lake, 56½ across the lake, and 119 to the Atlantic; total, 191 miles.

The estimate is:

From the lake to the west end of the tunnel........	£1,500,000
Descent to the Pacific......	500,000
From the Atlantic by canal along the river..........	2,500,000
	£4,500,000

DARIEN.

The remaining project takes one starting point, namely, the River Atrato, which is ascended for some distance and then quitted for one of its affluents, the Naipipi, or Truando, for example, whence it is proposed to cut a canal to Cupica Bay or Kelley's Inlet, near the Bay of Panama. Other projectors prefer continuing along the Atrato until its shalshallows are reached, and thence cutting a canal to the deep waters of the San Juan, which empties itself into the Pacific at Point Chirambira. This last was Humboldt's favorite project, and this is the point where the passage from sea to sea has been made, as described by him in his "Travels." It appears that the Padre of the district, in 1788, induced his Indian converts to cut a trench between the head waters of the San Juan and the upper stream of the Atrato, through the ravine De la Raspadura, and that he actually passed from ocean to ocean in a canoe during the rainy season. The cut is about three miles in length, and has been neglected of late years; but I was informed by the Alcalde of the place, when I was surveying about Cupica in 1847, that he had himself paddled through the cut. The total distance from sea to sea, from the mouth of the San Juan to the mouth of the Atrato, is about 225 miles.

At a later date (1854–5), an American gentleman named Kelley, entered warmly into this matter, and spent large sums of money in regular surveys and explorations. As Mr. Kelley's efforts at canalization have been most systematically carried out, and his surveys and estimates contain some sound information, I insert a few extracts:

The line will proceed direct south from the Bay of Candelaria, up the Atrato to its junction with the Truando, lat. 7° 15′ N. and long. 77° 8′ 32″ W., a distance of 67 miles 1,436 yards, whence it will diverge by the Truando to the S.W. and terminate at Kelley's Inlet, lat. 6° 57′ 32″ N. and long 78° W., a distance of 63 miles 1,216 yards. It will thus have a total length of 131,892 yards from sand bar to sand bar, with a minimum width and depth throughout of 200 and 30 feet respectively.

The difference in the height of the tides at the two extremities of the proposed route has been ascertained to be, at the entrance of Kelley's Inlet in the Pacific, 12 feet 6 inches at spring tides, and 10 feet 11 inches at neap tides; while the tidal rise at the mouth of the Atrato never exceeds two feet at any phase of the moon.

Colonel Lloyd estimated the mean level of the Pacific at 3.52 feet above that of the Atlantic; and more recently, M. Garella fixed it at 9.54 feet. Now, from a series of careful observations made in 1855 by Colonel Totten, the engineer of the Panama railway, in Navy Bay on the Atlantic side, and the Bay of Panama on the Pacific, it results that the difference, if any, is exceedingly trifling. Colonel Totten says in his report: "Although my observations make the mean level of the Pacific from 0.14 to 0.75 feet higher than the mean level of the Atlantic, this is probably owing to local circumstances alone. I think I may therefore state that there is no difference between the mean levels of the two oceans."

GENERAL CONSIDERATIONS.

You have now before you an account of Central America in general outline, and the three several points of vantage across which canals have been proposed somewhat more in detail; it only remains to choose between the rival proposals.

If we are to have a Central American Canal at all, there seems no reason to doubt that the choice will fall upon Nicaragua, for the general consensus of opinion appears unmistakably to incline in that direction, and most certainly no valid reason has been given against the adoption of that route by any one practically acquainted with the locality; on the contrary, the Americans, who certainly are the best judges, have made up their minds that Nicaragua offers the best, if not the only practicable passage for a canal across the Isthmus.

The English, unquestionably, will in no shape attempt to thwart this decision; indeed, in my opinion, we should do well to accept the situation, with this proproviso only, that the Nicaraguan Canal must absolutely be neutral territory, open to all comers, entirely unrestricted as a "highway of nations"

As with Suez, so with Nicaragua; if English commerce did not pass along the canal, it could not be made to pay any dividend on the capital required, and, therefore, it would be indeed lamentable if our Government allowed Quixotic notions, such as prevailed in 1846 with regard to free trade, to influence them in allowing English money to gravitate towards paying for the construction of the Nicaraguan Canal, so far, at least, as they can stop it, without taking very good care to have a *quid pro quo.*

Until a proper understanding is arrived at with the United States, ensuring us against the possibility of finding, some fine day, when we are least prepared for such an emergency, that the Monroe doctrine has been brought into play against English shipping, it will be politic to hold aloof from any participation in the undertaking. At the present moment, all the approaches to the Pacific are practically in the hands of the United States. In proof of this, it is only necessary to mention, that had it been necessary to telegraph to our squadron in the Pacific two years ago the sudden declaration of a war, that message would not have reached the British commander until his men-of-war had been captured in detail, and the capital of Vancouver's Island, with the munitions of war stored at Esquimalt bombarded and probably destroyed, to say nothing of the complete annihilation of our grain fleet, numbering not less than a thousand ships, freighted to convey to our shores the staff of life, amounting to nearly a million tons, not *quarters* of wheat. Surely, with such gigantic, if not vital consequences at stake, our Government will awake to the necessity of coming to a clear understanding with that of the United States before allowing the gate of the Pacific, now slammed in our face, to be also barred against us, in default of our intelligent participation in the enterprise of cutting a canal between the Atlantic and Pacific Oceans.

With regard to French interests, M. de Lesseps has made a mistake, which we may be sure, from the generous nature of his character, he will speedily rectify—he has simply followed a portion of the advice of my old friend, the far-famed Baron von Humboldt, in a letter to Mr. Kelley, of which I extract the following paragraph:

"The great object to be attained is, in my opinion, a canal which would unite the two oceans without locks and without tunnels. When the plans and sections can be placed before the public, a free and open discussion will elucidate the advantages and disadvantages of each locality; and the execution of this important work, which interests the civilized nations of the two continents, will be entrusted to engineers who have successfully distinguished themselves in similar enterprises."

M. de Lesseps is the last man to be discouraged by a failure; probably he already feels that he had better have relied on his own undoubted genius or followed up the proposals of his great and good patron, the late Emperor Napoleon III., whose wisdom and forethought are now conceded on all sides; indeed, I cannot do better than conclude this part of my subject by publishing, after long and close study, the views and opinions of that sagacious monarch on the Nicaragua Canal.

I quote from a very rare paper written by the late lamented Emperor; the extracts will, I am sure, find an honored place in the pages of the *Journal of the Society of Arts.*

EXTRACTS FROM A PAMPHLET WRITTEN IN 1847 BY NAPOLEON III.:

"There are certain countries which, from their geographical situation, are destined to a highly prosperous future. Wealth, power, every national advantage, flows into them, provided that where Nature has done her utmost, man does not neglect to avail himself of her beneficent assistance.

"Those countries are in the most favorable condition which are situated on the high-road of commerce, and which offer to commerce the safest ports and harbors, as well as the most profitable interchange of commodities. Such countries, finding in the intercourse of foreign trade illimitable resources, are enabled to take advantage of the fertility of their soil; and in this way a home trade springs up commensurate with the increase of mercantile traffic.

"It is by such means that Tyre and Carthage, Constantinople, Venice, Genoa, Amsterdam, Liverpool and London attained to such great prosperity, rising from the condition of poor hamlets to extensive and affluent commercial cities, and exhibiting to surrounding nations the astonishing spectacle of powerful States springing suddenly from unwholesome swamps and marshes.

"Venice, in particular, was indebted for her overwhelming grandeur to the geographical position which constituted her for centuries the *entrepôt* between Europe and the East; and it was only when the discovery of the Cape of Good Hope opened a ship passage to the latter that her prosperity gradually declined. Notwithstanding, so great was her accumulation of wealth, and consequent commercial influence, that she withstood for three centuries the formidable competition thus created.

There exists another city famous in history, although now fallen from its pristine grandeur, so admirably situated as to excite the jealousy of all the great European powers, who combine to maintain in it a Government so far barbarous as to be incapable of taking advantage of the great resources bestowed on it by Nature. The geographical position of Constantinople is such as to render her the queen of the ancient world. Occupying, as she does, the central point between Europe, Asia and Africa, she could become the *entrepôt* of the commerce of all these countries, and obtain over them an immense preponderance, for in politics, as in strategy, a central position always commands the circumference.

"Situated between two seas, of which, like two great lakes, she commands the entrance, she could shut up in them, sheltered from the assaults of all other nations, the most formidable fleets, by which she could exercise dominion in the Mediterranean as well as in the Black Sea, thereby commanding the entrance of the Danube, which opens the way to Germany, as well as the sources of the Euphrates, which opens the road to the Indies, dictating her own terms to the commerce of Greece, France, Italy, Spain and Egypt. This is what the proud city of Constantine could be, and this is what she is not, because, as Montesquieu says, 'God permitted that Turks should exist on earth, a people the most fit to possess uselessly a great empire.'

"There exists in the New World a State as admirably situated as Constantinople, and we must say, up to the present time, as uselessly occupied; we allude to the State of Nicaragua. As Constantinople is the center of the ancient world, so is the town of Leon, or rather Masaya, the center of the new; and if the tongue of land which separates its two lakes from the Pacific Ocean were cut through, she would command, by her central position, the entire coast of North and South America. Like Constantinope, Masaya is situated between two extensive natural harbors, capable of giving shelter to the largest fleets safe from attack. The State of Nicaragua can become, better than Constantinople, the necessary route for the great commerce of the world; for it is for the United States the shortest road to China and the East Indies; and for England and the rest of Europe, to New Holland, Polynesia, and the whole of the Western Coast of America.

"The State of Nicaragua is, then, destined to attain to an extraordinary degree of prosperity and grandeur, for that which renders its political position more advantageous than that of Constantinople, is that the great maritime powers of Europe would witness with great pleasure, and not with jealousy, its attainment of a station no less favorable to its individual interests than to the commerce of the world.

"France, England, Holland, Russia, and the United States, have a great commercial interest in the establishment of a communication between the two oceans; but England has more than the other powers a political interest in the execution of this project. England will see with pleasure Central America becoming a flourishing and powerful State, which will establish a balance of power by creating Spanish America a new center of active enterprise, powerful enough to give rise to a great feeling of nationality, and to prevent, by backing Mexico, any further encroachment from the north. England will witness with satisfaction the opening of a route which will enable her to communicate more speedily with Oregon, China, and her possessions in New Holland. She will find, in a word, that the advancement of Central America will renovate the declining commerce of Jamaica and the other English islands in the Antilles, the progressive decay of which will be thereby stopped.

"It is a happy coincidence that the political and commercial prosperity of the State of Nicaragua is closely connected with the policy of that nation which has the greatest preponderance on the sea."

In the remainder of his pamphlet, after fully considering the cost of the land, the Emperor enters at length upon his plan for combining colonization with the canal undertaking. The main features of this plan are well worthy the most careful consideration, and are here produced:

"We have stated that the secondary

profits of the canal would arise from the increase in the value of the soil. According to our information, the Government of Nicaragua would cede to the company all the land lying on the right and left banks of the canal throughout its entire course, to an extent of two leagues inland, forming three hundred square leagues, or about 1,200,000 acres. These 1,200,000 acres are at the present moment worth 1s. 6d. per acre. The proposed gift by the Government of Nicaragua to the company is, therefore, now of the value of £90,000. If we deduct from the above number 200,000 as probably incapable of cultivation, and 300,000 more that would be required for the service of the company, producing no income, or as concessions to its engineers, servants, etc., there will remain 700,000 acres to explore and improve. The canal being accomplished, it will be easily granted that these lands may in all probability bear a value of £2 per acre.

"£2 per acre. Let us put it at £1 per acre only, and we shall have a property of £700,000 vested absolutely in the company, for we must not forget that the soil is here very fertile; that they frequently have more than two harvests a year; that the indigo produced in this country is better than that produced in the East Indies; that the tobacco is as good as that at Bavaria; that coffee and sugar are easily produced; that the forests are filled with Brazil wood; that there are mines to work; and, finally, that the waste water thrown off the canal works would afford power for manufacturing purposes. It is thus evident that if the company should limit itself to the disposal of these lands when the canal is complete, they would derive great profit were it only by the increase of value; but, in our opinion, there is a greater advantage to be derived from their detention.

"We firmly believe that it is important to continue, with the construction of the canal, the project of colonization, in order that the two undertakings should assist each other, and to enlist as share holders the large mass of emigrants who annually depart for America, and who, according to the statistical information gathered up to this day, set forth with an average sum per head of £20.* Thus the shares would be placed in hands most interested in the success of the undertaking; for those who join an enterprise for the sake of investment, and not mere gamblers, ensure the solidity of an undertaking.

"The capital of £4,000,000, which we presume to be necessary for the construction of the canal, should be divided into 400,000 shares of £10 each. By paying down the value of one or more shares, the emigrant shareholder would be entitled on his arrival in America, to such accommodations as would enable him to overcome the first difficulties necessarily attendant on early steps in colonization. Every emigrant shareholder would receive from the company twenty acres of land to cultivate, as well as the implements necessary for that purpose.

"The 700,000 acres of land would be thus distributed among 35,000 emigrants, and sold to them on the following terms: Ten years' time would be allowed for the emigrant shareholder to pay the company the price of the twenty acres allotted to him, as well as the outlay incurred by the company in procuring him dwelling, food, and all the accommodations required. The payments should be made by annual instalments, and proportionate to the progressive increase of value likely to increase every year in the property.

"So the whole of the first year having been entirely taken up by preparing and tilling the ground, the emigrant shareholder should not be made liable for any payment whatever during that time. The annual instalment should begin to be paid off at the end of the second year, and accomplished in the progressive manner indicated in the following table:

* We read in the *Journal des Débats*, of the 3rd May, 1846, that the society formed at New York, the 31st of March, 1784, to assist the indigent Germans in the United States, had just celebrated the sixty-second anniversary of its foundation. On this occasion they have published a pamphlet which states, amongst other things, that the number of German emigrants which arrived during the last year in the city of New York alone amounted to 30,567, each of them having an average sum of £20 sterling. Of these emigrants 12,225 arrived from Havre in seventy-eight ships; 9,647 from Bremen in seventy-seven ships; 3,718 from Antwerp in twenty-five ships; 2,525 from Hamburg in twenty-four ships; 1,959 from Rotterdam in thirteen ships; 493 from Ghent, London and Liverpool, in five ships. The greater part took their direction towards the Southern States. In 1814, there arrived only 17,999 German emigrants at New York.

	Per Acre. Per Annum.		
At the end of the first year..........	£0	0	0
" " second year.......	0	1	0
" " third year.........	0	1	6
" " fourth year........	0	2	0
" " fifth year..........	0	2	6
" " sixth year.........	0	3	0
" " seventh year......	0	3	6
" " eighth year........	0	4	0
" " ninth year.........	0	4	6
" " tenth year.........	0	5	0
" " eleventh year......	0	5	6
	£1	12	6

So every acre of land will procure to the company, in the course of eleven years, a net profit of £1. 12s. 6d., and, consequently, 700,000 acres of land will bring, in the above-stated lapse of time, the corresponding profit of £1,137,500.

"The company would establish as many villages as would be necessary for the number of colonists. Each village would be erected on the most healthy spots, and in the vicinity of a river. It would be composed of 200 dwellings, each dwelling being appropriated to one family. A village would then cost:

200 dwellings at £4 each................	£800
Maintenance for the first six months, and seed, at £4 per family..................	800
Church, stores and schools..............	280
Casual expenses...	120
	£2,000

"If we divide this sum by the number of families, we shall find that the outlay will be £10 per family, in ten years to be reimbursed as above stated. Now, let us suppose that in about ten years the company has established 175 villages containing 35,000 families; the expense will have been £350,000, which the company will be reimbursed by the annual progressive rate. As each of these families have been enabled to buy and pay for twenty acres of land, at the progressive rate above mentioned, the company will have received for 700,000 acres the sum of £1,137,500, from which, deducting £350,000, the outlay for the construction of the villages, there will remain a clear profit of £787,500, exclusive of the interest received on the outlays. We must also remark that the colonists being shareholders, will have paid £767,500 to themselves in their capacity as a company; then there would be a perfect amalgamation of interests between the shareholders and the colonists, who would be equally interested in the success of the undertaking. Thus deducting the sum from the amount of £4,000,000 necessary for the construction of a canal, the capital expended would be about £3,200,000 only, bringing a net profit of £600,000, or ten per cent. per annum.

"At present, when the colonist goes to America, he finds no dwelling, no advance of capital, and often no employment; on our plan, on the contrary, by means of a share, he is sure to find, on arriving in America, a wholesome dwelling, livelihood for six months, fertile lands, and a community already settled. Moreover, a part of the money paid for the purchase of his land would come back to him as a shareholder, and in about ten years his property would not only be freed from all burdens, but he might expect at that period that both his share in the canal and his land would be doubled in value.

"Thus our project protects all interests; the capitalists realize large profits, and the emigrants partake of the benefits with a moral certainty of future prosperity. This neglected country speedily changes to florishing towns, its lakes are covered with fleets, and its wealth is increased by the progress of agriculture and commerce.

"Central America can emerge from her present languor only by following the example of the United States, namely, by borrowing from Europe labor and capital for this their first object. Independent of the advantages of its geographical position and of the fertility of its soil, the State of Nicaragua presents to European emigrants advantages which are not to be found in the United States. In the North of America, the population settled itself in the beginning on the Eastern coast, gradually extending inland. As long as the uncultivated lands were not far from the sea, the European emigrants easily found employment; but now the case is altered, and the great number of foreigners that daily arrive in the United States become for the following reason a burden to the nation. The uncultivated lands, where adventurers may easily find employment, are three hundred leagues from the coast, and as in most instances the emigrants are destitute of means to reach those remote districts, they become in the towns on the coast a prey to indolence and misery.

"In Central America the reverse would be the case; the indigenous population has settled by preference on the coast of the Pacific Ocean, deserting all that part situated opposite the ancient world, so that when the country is in a position to require colonists and European laborers, they may arrive, through the canal, to places already inhabited, and the population will gradually extend from the west to the east, and not, as in the United States, from the east to the west, thus getting nearer to Europe in proportion as it increases, and offering facilities to the new colonists. till they reach the extreme borders of the country.

"The prosperity of Central America is connected with the interests of civilization at large, and the best means to promote the welfare of humanity is to knock down the barriers which separate men, races and nations. This course is pointed out to us by the Christian religion, as well as by the efforts of those great men who have at intervals appeared in the world. The Christian faith teaches us that we are all brothers, and that in the eye of God the slave is equal to the master, as the Asiatic, the African, and the Indian are alike equal to the Europeans. On the other hand, the great men of the world have by their wars comingled the various races of the world, and left them some of those imperishable monuments which, in leveling mountains, opening forests and canalizing rivers, has a tendency to upset these obstacles which divide mankind, and to unite men in communities, communities in people, people in nations. War and commerce have civilized the world. The time for war is gone by; commerce alone pushes its conquests. Let us, then, open to it a new route; let us approximate the people of Oceania and Australia to Europe; and let us make them partakers of the blessings of Christianity and civilization. To accomplish this great undertaking, we make an appeal to all religious and intelligent men, for this enterprise is worthy of their zeal and sympathy. We invoke the assistance of all statesmen, because every nation is interested in the establishment of new and easy communication between the eastern and western parts of the globe. Finally, we call upon capitalists, because whilst they are promoting a glorious undertaking, they are sure to derive a large profit thereby."

PART III.

PERSONAL EXPLANATION.

Before proceeding to place before you the views and opinions which I entertain in respect to cutting a canal across Central America, it is only right that I should indicate the range of my experience, and show cause for the confidence with which I express those views and opinions.

In this respect, I cannot do better than quote from my printed address to the Paris Congress, which I was unable to attend, owing to a severe accident, breaking the left knee-cap, which literally tied me, at that time, by the leg:

"I may say that between the years 1845 and 1851 I was engaged, 'on and off,' on the surveys of the coast line of the Pacific Ocean, from Cape Corrientes to the port of Realejo, especially in and around the Bay of Panama—a coast of about 1,000 miles—my attention being particularly directed to the Gulf of San Miguel, the approaches of the Nippi, to the Chepo, or Bayano river, a route having the recommendation of possessing a waterway approaching the Atlantic Ocean nearer than any other, and to the magnificent harbor of Realejo in Nicaragua.

"On the Atlantic coast I have had an equal, if not more extensive, experience.

"Between 1859 and 1861 I was stationed as senior naval officer between Cape Gracios a Dios and Colon, or Aspinwall, and since that time I have often crossed Central America. I have been no less than six times through Nicaragua, and possess an accurate section with the theodolite between the Atlantic and the Lake of Nicaragua, on a line parallel to and about 40 miles distant from the river San Juan.

[That section you will see on the wall behind me.]

"I have pointed out fully in my works,

'The Gate of the Pacific, 1863,' and 'Dottings by the Roadside, 1869,' and this meeting is of course aware that there are still other routes to the northward; such as that through Tehuantepec and Honduras, for which latter State I was for some time Special Commissioner, and for more than a year devoted my best attention towards completing the Inter-Oceanic Railway; but circumstances over which I had no control prevented me from achieving that object. I am bound to say, however, that I still have faith in it, and believe the Government of the country would satisfy the just claims of their creditors to the last dollar, if only those creditors would bring a gentle pressure to bear, and insist upon payment, if not in money, then in land, in exchange for their bonds."

POLITICAL.

There is a phase of the question before us to-night which must not on any account be neglected, for, after all, it has quite as important a bearing as the physical geography, *plus* the engineering considerations of the enterprise, both put together; I mean the political or diplomatic aspect of the situation. We have now to ask ourselves how far the enterprise of effecting a junction between the Atlantic and Pacific, by means of a canal capable of transporting ships from one ocean to the other, across the Isthmus of Central America, may affect the political relations of the great nations affected by it.

To arrive at a solution of this problem, I must first point out the nature of interest which each of the nations named seems to possess in the proposed enterprise.

In the order of interest I have already adopted, I may point out—1. That a canal across Central America would be the gate of the Pacific to the United States, a gate, moreover, which no American statesman would allow for one moment to be in the governmental keeping of any other country whatever. 2. That England's concern in the undertaking is chiefly to further a supply of cheap grain from California; last year no less than a thousand sailing vessels, averaging 1,000 tons each, rounded Cape Horn, bound for England with a cargo of the "staff of life," and it is obvious that by shortening the passage and avoiding Cape Horn, freights and insurance would rule less, and consequently grain could be placed in the English market at a lower price.

At the same time it may be as well to warn the United States that in this case England's necessity would not be their opportunity, for there are other places besides California from whence we may draw a supply of grain, with far more ease and certainty, and at considerably less cost. The Euphrates Valley, for instance, which in ancient times was the granary of the world, and which England, by merely lifting up her little finger, could, within a very short time, restore to its pristine importance, and that not only in British interests, as a great field for British colonists, but eminently in furtherance of her duty, under the secret treaty, by advancing the prosperity and civilization of Asia Minor.

But taking a broad view of the position, it is quite in accordance with the best interests of the United States to join hand and glove with England in the canalization of Central America; at all events, without the co-operation of English capital and trade, this is certain, the canal would not prove a paying concern to the United States; indeed, it would take very much the character of a white elephant.

With regard to France, the canal is more a matter of sentiment than a real want, and in point of fact the French people for the next century can afford to remain in blissful ignorance, whether a canal across Central America exists or not. Nevertheless, the proposed work is of a nature to command the respect if not the enthusiasm of the French people, and, therefore, taking all the *pros* and *cons* into consideration, it may be quite worth the while of France to join with England and America in a sort of co-partnership to make the proposed canal a grand international work. The cordial union of the three nations is very desirable upon every ground, but how is this to be effected? By treaty? Certainly not; for treaties, now-a-days, are only made to be broken.

How, then, can this union be made? Why, in a business-like manner, for business purposes. Let the three nations join hands and become partners for the purpose of carrying out this grand undertaking, and let the three nations weld themselves into one, as it were, by each undertaking a guarantee of 1 per cent. on the capital required.

The requisite money, no matter what the amount, would then readily be raised at 3 per cent., under a joint guarantee of the greatest nations in the world.

ADMIRAL AMMEN, U.S.N.

Before placing before you the suggestions I have to offer, it is only fair that I should inform you of the views of the American Government in respect to the Interoceanic Transit, as laid down by Admiral Ammen, at Paris, in May last.

In his address to the Congress, he clearly and unmistakably points to Nicaragua as having the preference, after exhaustive surveys, overy other part of the Isthmus of Central America.

The facts and figures mentioned by Rear-Admiral Ammen are conclusive, as will be seen by the following summary of the information which he gave to the Congress:

Extracts from the Address of Rear-Admiral Daniel Ammen, U. S. Navy, Vice-President of the Congress, Member of the Inter-Oceanic Canal Commission, appointed by H. E. the President of the United States, in compliance with a resolution of the Congress of the United States of America.

NICARAGUA ROUTE.

The rainfall is comparatively small. Our observations at Lake Nicaragua, extending over one year, show an annual rainfall of forty-eight inches, or 1.22 meters. There is a distinct dry season of between five and six months, when work in progress would not be delayed or injured, and but little interruption need be apprehended in the rainy season on that section of canal between the lake and the Pacific, as the rain generally falls at night, with occasional showers during the day.

There is abundant good stone, hydraulic and other lime, wood, and bamboos, which may be found very advantageous in the construction of harbors.

There is a considerable population, well disposed, and when they can have remunerative employment, fairly industrious. The country has an abundant cattle supply of good quality for food, and other productions which would furnish the main subsistence for laborers on the canal, with a convenient water transportation in general along the line of ship canal as located, and lake communication with an extensive, populated and fertile region. This water communication can be greatly increased, by the construction of a six-foot canal to Lake Managua, at an inconsiderable cost, and when completed would make the supplies of all kinds superabundant. Between Lake Nicaragua and the Pacific, near the line of the projected canal, several passable roads exist, and whatever other roads might be required over this short distance could readily be made at inconsiderable cost.

There is an inexhaustible water supply in its lake of 2,800 miles of superfice, which equalizes floods and makes the daily changes small in the discharge.

It has an excellent harbor on the Pacific coast at San Juan del Sur, convenient for anchorage as Brito itself would be improved as a harbor, inasmuch as the vessel in transit would have time to regulate her steam and be pointed fair to enter the canal at any assigned time. This reduces the necessity of a harbor at Brito to simply securing a perfectly smooth entrance to the canal.

Lake Nicaragua affords every facility for an interchange of cargoes that may be desired.

The west coast and the valley of the lake are, as compared with the eastern slope, comparatively healthy, and upon the eastern slope a considerable part of the labor can be done by means of dredging machines.

The approaches to both entrances are superior in advantages to those of either of the two other two routes with which the Nicaragua route is compared.

These considerations would seem to warrant the belief that cost of construction, including material, would be far less than upon either of the two other routes compared, as will be more fully shown hereafter.

PANAMA ROUTE.

The mean annual rainfall at Aspinwall in a series of seven years is found to be 124.25 inches, or 3.15 meters. A dry season exists, but it is limited to two or three months, lessening the effective time for labor and of comparative healthfulness of the laborers employed, the wet being the sickly season.

No building material suitable is known in that region. The ties and railroad telegraph poles on the Panama Railroad are brought from Carthagena or elsewhere.

The population is inferior to Nicaragua in ability to furnish subsistence for a large number of laborers.

By means of the railroad already constructed, a canal under construction would have a convenient transportation at whatever cost might be agreed upon.

The cost of the feeder and adjuncts, as well as other disadvantages, notwithstanding the shortness of the line, as shown by maps, plans and estimates, make a total of $94,511,360, as against those of the Nicaragua route of $65,722,137 on a common basis of cost of material and labor, when in Nicaragua the material is near at hand and subsistence abundant, and on the Panama route, or in its region, there is no material for construction, inferior subsistence and less favorable climatic conditions for labor, as before stated.

DARIEN ROUTE.

Although the mean annual rainfall is not known, there is no doubt of the fact that it is largely in excess of the rainfall in Aspinwall, on the Panama route. There is only a nominal dry season, as at any time a precipitation of several inches is likely to occur, and actually does occur many times yearly during the so-called "dry season."

The building material supposed to be available is confined to wood.

The population is so scant as to be unable to furnish either assistance or subsistence for even an inconsiderable number of laborers.

The River Atrato would furnish transportation to the mouth of the River Napipi. Along the line of the projected canal the country is alternately rough and covered with swamps, so that great labor would be necessary to construct roads to secure even wagon transportation, for subsistence, and material for construction.

Under such conditions the projected feeders requisite would be made at great additional cost, as well as the projected tunnel and locks. In dimensions the projected tunnel is as follows: Length, 5,633 meters; height, 35.96 meters; width, 18.29 meters.

On the Atlantic slope there are twelve projected locks of 3.14 meters lift, and on the Pacific slope ten of 4.54 meters lift, the summit level being 43.59 meters above mean tide.

With the view of having a definite comparison, the estimate for material and labor, so far as they are identical, were made on a common basis with Nicaragua. The cost of this basis is given as $98,196,894, but it is quite apparent that with the lack of material convenient, of subsistence and transportation, as well as the absence of a dry season, and, above all, the impossibility of making even an approximate estimate of the cost of a tunnel under such conditions, that the actual cost of the execution of the work would be far in excess of the estimate.

The same physical conditions—the absence of a dry season and a general lack of material for construction, except wood, and the lack of subsistence—were found to exist by all our parties at various times on what is known properly as the Isthmus of Darien and of all the region lying south of it.

It is impossible not to be struck with the common sense of these remarks of Admiral Ammen. I know the Napipi, I know Panama, and I know Nicaragua, and I cordially indorse the American preference for the latter.

SUGGESTIONS.

I have now to offer a few suggestions, and propose a plan by which I hope to aid those who will embark in the enterprise of constructing a canal, through Nicaragua, from the Atlantic to the Pacific.

The great difficulty to be overcome in the construction of a canal across Nicaragua is the making and maintaining the harbor of Greytown, on its Atlantic terminus. My friend, the late Mr. Robert Stephenson, the great engineer, when I was with him in Egypt in 1858, used to say that he was acquainted with the deltas of all the great rivers of the world, but that he was not aware of a single instance in which a harbor was maintained at the mouth of any of such rivers. Now, the River San Juan de Nicaragua has a delta at its mouth, but no other delta in the world is so capricious. In 1856, a squadron of H.M.'s ships rode securely at anchor in the harbor of Greytown; but in 1860, when I was stationed as senior naval officer in that locality, the sand bar, which made the harbor, stretched across very nearly from shore to shore, leaving only sufficient depth of water for the very smallest coasting craft. A few years later there was again a considerable opening, and so matters went on, but now for some time it has been completely closed. A strong norther is sufficient to shut up the harbor, while a high river will re-open an entrance. Mr. Robert Stephenson's dictum, therefore, as to the enormous difficulties to be encountered in the attempt to form a harbor at the delta of any great river, is more than borne out in the case of Greytown.

I am well aware that an exception has occurred to this ruling in the case of the Mississippi, where Mr. Eads has succeeded in obtaining a depth of twenty-seven feet, under high pressure from Congress; but the problem is, how to maintain that depth at anything like a paying cost. If the engineering difficulties could be overcome, in forming and maintaining a harbor at Greytown, the other obstacles to the opening of the canal from ocean to ocean would be found of secondary importance, although it cannot be denied that the River San Juan is more or less encumbered with shoals and rapids, and with sudden rises in the rainy season of from 20 to 40 feet, making the control difficult; but to my mind Greytown itself would alone completely swamp the enterprise. Under these circumstances it seems desirable to suggest an alternative route, with very different dimensions for the canal, and a consequent diminution of cost from that at present contemplated.

Starting from Monkey Point, now called Pim's Bay, on the Atlantic, 40 miles north from Greytown, I should commence by cutting a canal from the inner part of that bay down to the Rama river, a distance of about 10 miles. The Rama river itself carries deep water about twenty miles into the interior; the remaining seventy miles to the Lake of Nicaragua would traverse land, offering no particular difficulty, as may be seen by the section which is suspended behind me.

From San Miguelto, on the Lake Nicaragua, by way of Tipitapa, to the northern shores of Lake Managua, there is nothing which an engineer would consider a difficulty in these days. The remainder of the canal to the *embarcadero* of Port Realejo, on the Pacific, can scarcely be said to afford a field for engineering skill, the great difficulty being the supply of water for the canal, but, inasmuch as lake Managua is higher than the Pacific, this is not insurmountable. The distances by this route would be as follows:

	Miles.
Pim's Bay to Lake of Nicaragua..	100
Lake Navigation....	85
Rio Panaloya or Tipitapa........	20
Lake Managua..................	40
Lake to Realejo....	45
	290

occupying, at four miles an hour, say, three days.

I must point out that, in this scheme, a deep-water canal is not even contemplated; a depth of eight feet would be amply sufficient, the vessels being raised and transported on pontoons by the process which has been successfully used in the Victoria Docks for years. A ship of the largest tonnage is raised within half an hour, and the pontoon, only drawing four feet of water, is hauled, with the ship securely resting upon it, into a shallow dock for its reception. It is needless to say how considerably the cost of the canal works would be reduced if such a plan were adopted, while there are other advantages, such as cleaning the ship's bottom *in transitu*, just as if she were in dock, the doing of which would effect a saving to the owners, by increase of speed, almost, if not quite sufficient, to pay the canal dues.

Another suggestion I wish to make is this: first open in the proposed direction a complete transit from Pim's Bay to Realejo by means of a railroad and lake steamers. It must be apparent how materially this would cheapen the canal works, if only by enabling the engineers to avoid many an obstacle which, without such a pilot, would be sure to crop up and impede the works. Besides, such a transit would, I have reason to believe, earn enough to pay interest on the canal capital within a year of its construction, and I believe that the works of the railroad, a light single line, might be finished in about a year after turning the first turf. The advantages to be gained by adopting the plan I have just proposed seem to me obvious; but I will go even farther, and suggest that this railroad, from Pim's Bay to the Lake of Nicaragua, should be built, even if the canalization of the River San Juan is determined upon, because then the engineers could be supplied with all their requirements with the stream instead of against it.

An estimate is always a delicate matter to deal with, and I shall not attempt to go into detail, but take the outside sum of £20,000 a mile, and the outside length of my proposed route at 300 miles, upon nearly one-half of which distance no outlay will be needed, so that, practically, my estimate is £40,000 a mile; the total sum required would then amount to six millions as the outside cost of a water communication from ocean to ocean, including the pilot transit I have already mentioned.

I do not believe there would be any difficulty in raising six millions sterling in America, England and France, for such purposes, if only a land warrant for a five acre plot were given as a bonus with each £10 share. This would necessitate a grant of land with the concession of some 5,000 square miles on each side of the Canal of Nicaraguan territory, between the Atlantic and the Lake of Nicaragua, and would, no doubt, be readily given. But I think it will be admitted by everybody, that such a work as joining the Atlantic and Pacific Oceans should not be left to private enterprise. It is surely a work of sufficient magnitude to enlist international support, especially if that support can be shown to require a pecuniary outlay only of the smallest dimensions, and that only for two or three years.

Let us assume the capital to be, as I said just now, six millions. Now, if England, America and France would join hands, and each guarantee 1 per cent. on that amount, we should have a joint guarantee of 3 per cent.—inducement sufficient for English investors alone to take up the whole sum in less than a week. What is 1 per cent. on £6,000,000? £60,000 a year—a sum, I venture to think, annually wasted on any vote exceeding one million of the Navy esti mates. And what do we get for our money? Why, at the least, a consolidation of the friendly feeling between this country, the United States and France, far more lasting and binding than could be effected by any treaty merely guaranteeing the neutrality of the route. We should be joint proprietors of the canal, and that, in my judgment, is the only safe arrangement to be made, consider ing the tremendous stake involved.

CONCLUSION.

In the preceding remarks, I have endeavored to place before you a bird's-eye view of the efforts which have been made, notably by the Paris Congress, to resuscitate the project of cutting a canal across the Isthmus of Central America; I have also tried to give you a general idea of Central America itself, and the various proposals made to effect a junction across it: and I have pointed out why the isthmus at Nicaragua is more favorable for the construction of a canal than at Panama; finally submitting to you my own plans and proposals based upon long practical experience on the spot. At last the day appears to have arrived, for which I have worked hard for twenty years at no mean expenditure of time and money.

If the Government is blind to British interests and has lost that spirit of enterprise through which our forefathers raised the nation to its present greatness; if the Government neglect to take up a proper position towards a project so closely interwoven with the future of the United Kingdom, then such degeneracy must be deplored, and theirs is the responsibility.

My interest in Nicaragua, or rather Mosquito, is as great as ever; I still own considerable property there, many thousand acres of land, and the freehold of the Atlantic Terminus at Pim's Bay, but I say now to the present Government, as I wrote to that of 1859, and recorded in my book, "The Gate of the Pacific," published in 1863, that I simply hold this property in trust for the national benefit, and my great ambition is that it may prove useful to further the prestige and maintain the power of old England.

THE MEASUREMENT OF EARTHWORK BY THE PRISMOIDAL FORMULA.

By C. P. AYLEN, B. C. E.

Written for VAN NOSTRAND'S MAGAZINE.

In the application of the prismoidal formula to the measurement of earthwork the deduction of the mid-section requires more care than it generally receives. The usual method is to take the means of the heights and widths of corresponding cuttings in the end sections for heights and widths of points in the mid-section. In this manner the mid-area is easily computed. The results thus obtained are perfectly correct in level ground, and even in rough ground, results sufficiently accurate for practical purposes may be obtained by close cross-sectioning, though at considerable sacrifice of labor. A general method of computation may be easily derived from the general formula, which will satisfy all cases likely to occur in practice, and give results which, in theory at least, are mathematically correct. Let the volume of an earthwork prismoid, consisting of one station of a railroad excavation, be required. Let the center height of one end above the intersection of the side slopes be h_0; other heights to the right of the center line, h_2, h_4, h_6, &c.; and their respective distances out, d_2, d_4, d_6, &c. Let h'_0 be the center height of the other end section, h'_2, h'_4, h'_6, &c., heights, and d'_2, d'_4, d'_6, &c,, their respective distances out to the right; h'_1, h'_3, h_5', &c., heights, and d'_1, d'_3, d'_5, &c., their respective distances out to the left. Let 1′, 3′, 3, &c., denote the points whose heights are h'_1, h'_3, h_3, &c., and whose distances out are d'_1, d'_3, d_3, &c., respectively. If 1′, 3′, 3, is one of the surface planes of the prismoid, and if vertical planes are passed through 31′ and 33′ to the side slopes, we have a wedge-shaped solid whose end area is

$$\tfrac{1}{2}(d'_3-d'_1)\ [h'_1+h'_3-\tfrac{1}{s}(d'_3+d_1')],$$

and whose mid-area is:

$$\tfrac{1}{8}(d'_3-d'_1)[h'_3+2\ h_3+h'_1 \\ -\tfrac{1}{s}(d'_3+2d_3+d'_1)]$$

where s is the tangent of the angle which the side slopes make with the vertical. Consequently the mean area is, by the prismoidal formula,

$$M=\tfrac{1}{6}(d'_3-d'_1)[h'_3+h_3+h'_1 \\ -\tfrac{1}{s}(d'_3+d_3+d'_1)]\quad . \ . \ . \quad (A)$$

The mean areas of the wedge-shaped bodies beneath the outer surface planes are found in a similar manner. Their sum, minus the area of the grade triangle, is the mean area of the whole prismoid, which, multiplied by its length, gives its volume. It will be noticed that by this method not only the end-sections, but also the distribution of the surface planes must be known, otherwise it is difficult to see how the prismoidal formula, or any other formula, can give correct results. If the arrangement of the surface planes is not given, the form of the solid is not known, and consequently its volume cannot be determined. When the work is partly in excavation and partly in embankment, the formula must be slightly modified. The intersection of grade with the surface of the ground should be determined in the field. If a vertical plane is passed through this intersection—extending downward to the slope of the excavation and upward to the slope of the embankment, we have two prismoids, one containing the excavation, and the other the embankment. The mean areas of the portions above or below the surface planes are found as before, except that we must put

$$M=\tfrac{1}{6}(d_3'-d_1') \\ [h_3'+h_3+h_1'+\tfrac{1}{s}(d_3'+d_3+d_1')]\ .\ .\ .\ (B)$$

when the plane 33′1′ lies between the center line and grade. From the mean area of each of these prismoids the mean area of its respective grade prismoid must be subtracted. If g is the center height of grade above the side slope, δ and δ' the distances out of the intersection of grade with the surface, the mean area of the grade prismoid is

$$\tfrac{1}{6}s[(g\pm\tfrac{1}{s}\delta)^2+(g\pm\tfrac{1}{s}\delta)(g\pm\tfrac{1}{s}\delta')+(g\pm\tfrac{1}{s}\delta')^2] \quad . \; . \; . \quad \text{(C)}$$

The positive sign is used when the cut or bank extends beyond, and the negative when it does not reach the center line. Here follows two simple examples, which will show the application of the principles enunciated.

Example I. $s=\frac{3}{2}$, half width of roadway, 9 feet, length 100 feet, and other data as tabulated.

Station From	Station To	Subscript.	*h.*	*h'.*	*d*	*d'*	Surface Plane.	$3g+eh$	$\frac{1}{s}ed$	Diff.	Diff. in width.	6 M to slopes.	M to slopes.	M to grade.	Cu. Yds.
0	1	0	8	13.6	0	0	0′20	51.6	18	33.6	27	907.2			
		2	12	10	27	24	22′0	53.6	34	19.6	24	470.4			
		1	4	8	15	21	01′0′	47.6	14	33.6	21	905.6			
							1′10	38.0	24	14	15	210.0	382.2	328.2	1215.6

The first eight columns contain the data. The first two need no explanation, the third contains the subscripts of the letters in the next four columns; for instance, h_2' is found opposite 2 in the column headed h', with the difference that heights are here measured from grade instead of from the intersection of the side slopes, three times the height of the grade triangle being added to the sum of the heights. The eighth column gives the surface planes.

Example II. Partly in excavation and partly in embankment. In excavation, half width of road-bed, 11 feet, $s=1$; in embankment, half width of road-bed, 9 feet, $s=1\frac{1}{2}$, length 100 feet; other data as tabulated.

Station. Fr'm	Station. To	Subscript.	*h*	*h'*	*d*	*d'*	Surface Plane.	$3g+eh$	$\frac{1}{s}ed$	Sum or difference.	Difference of widths.	6 M to slopes. Cut.	6 M to slopes. B'k	M to slopes. Cut.	M to slopes. B'k	M area of grade prismoid. Cut.	M area of grade prismoid. B'k	Mean area. Cut.	Mean area. B'k	Cu. yards. Cut.	Cu. yards. B'k
0	1	2	6	5	17	16	0′20	44	17	27	17	959									
		0	2	3	0	0	22′0′	47	33	14	16	224									
		1	0	0	4	3	01′0′	38	3	41	3	123									
		3	−4	−2	15	12	1′10	35	7	42	4	168		162.3		105.2		57.2		211.7	
							3′31	—24	20.7	3.3	11		36.7								
							13′1′	—20	12.7	7.3	9		66		17.1	1	10.1		70		25.9

In this example the minus sign is used to distinguish quantities in embankment from similar ones in excavation; having no algebraic significance it is not used beyond the ninth column, where it is useful in separating the part in excavation from that in embankment.

It is sometimes desirable to know the position of the center of gravity of a portion of earthwork. In that case the following theorem may prove useful:

If A_1 and A_3 are the bases, A_2 the mid-area and l the length of a prismoid, the distance of its center of gravity from A_1 is

$$u=\frac{o.A_1+1.4A_1+2A_3}{A_1+4A_2+A_3}\,\frac{l}{2}$$

From this it follows that if A_1, A_3 A_5, are equidistant cross-sections of an excavation or embankment, A_2, A_4, interpolated mid-areas, and l its length, the distance of its center of gravity from A_1 is

$$u=\frac{o.A_1+1.4A_2+2.2A_3+3.4A_4+4A_5}{A_1+4A_2+2A_3+4A_4+A_5}\,\frac{l}{4}$$

When the volume of a mass of earthwork is required its center of gravity may also be found, by this formula, without much extra labor.

ON THE HARDENING, TEMPERING AND ANNEALING OF STEEL.*

From "Iron."

It does not appear that any attempt had been made in this or in any other country to discover the theories of the constitution or properties of steel, till Karsten in 1827 investigated the conditions of carbon in iron, and Jullien in 1852 deposited at the Academy of Sciences, Paris, a paper termed "L'Explication de la Trempe." From that period a good deal has been written chiefly by French metallurgists.

I.—NATURE AND COMPOSITION OF STEEL AND CAST IRON.

Karsten in 1827 says that carbon is contained in iron in three different ways:—(1) As free carbon or graphite. (2) Combined with the whole mass of iron. (3) In the state of polycarburet, dissolved in the mass. In 1852 Jullien advocated, if he did not originate, the theory that iron and carbon do not combine (as true chemical combinations), but that the compounds formed by the two substances are what he terms "solutions," or, as we should translate it into English, only mechanical mixtures. Following Karsten, Berzelius, and others, he holds that amalgams and alloys are definite combinations dissolved in excess of one of the components. He defines "combination" to be a union of elements in definite proportions, the resulting body being different from either component and from any of their other definite combinations. "Solutions," or mechanical mixtures, on the other hand, may occur in any proportions, and the resulting mixture participates in the properties of each component in proportion to its quantity. Your committee find it difficult to acquiesce in the latter portion of this statement. For example, the addition of increasing proportions of tin to copper results in producing harder compounds, instead of softer. Under certain circumstances the addition of a small proportion of tin to cast iron greatly increases its hardness. Barba adopts Jullien's view, and defines steel to be a solidified solution of carbon in pure iron: (Les aciers sont des dissolutions solidifiées de carbone dans du fer chimiquement pure.) Osborne seems to think that carbon exists both in a combined form and uncombined, disseminated in the latter case as graphite; but he does not define clearly what he means by the word "combined." Caron considers the union of the two substances to be a mixture. Gruner takes the same view. Akerman adopts the view that carbon occurs both in combination and as graphite; and also the view of Rinman, that combined carbon may be partly intimately combined, when it may be called "hardening carbon," and partly incompletely combined, when it may be called "cement carbon." He does not define what he means by combination, whether in definite proportions or not. Your committee have not found any modern author holding the opinion that the various combinations of iron with carbon, and with other substances found in steel and cast iron, are definite chemical unions with excess of either one or other of the component bodies. The elaborate evidence adduced by Jullien, which does not appear to have been combated, makes it highly probable that steel and cast iron are only mechanical mixtures of carbon and some other substances in pure iron.

II.—QUANTITY OF CARBON IN STEEL AND CAST IRON, AND ITS STATE.

Barba considers that the solution of carbon in molten iron follows the ordinary laws of solution, that is:—(1) The quantity of carbon which iron can contain in solution increases with the temperature. (2) By slow cooling a part of the carbon separates from solution and is brought into a state of mixture. (3) With rapid cooling, or sufficient exterior pressure, the greater part of the carbon remains in "solution;" rapid cooling acting by the pressure it produces; and, if the carbon is merely mixed, exterior pressure producing solution more or less complete according to the intensity of

* Report to Research Committee of the Institution of Mechanical Engineers.

the pressure. (4) The temperature at which steel solidifies decreases as the quantity of carbon it contains augments. He remarks that experimental demonstration is wanting to show that pressure is favorable to preserving "solution" when cooling. Osborne says that rapid solidification favors the retention of carbon in the combined state, and by that means it is possible to change grey cast-iron into white. Jullien states (1852) that the properties which the solutions of carbon in iron exhibit are due exclusively to the rate at which the hot solutions are cooled. Following Karsten, he says that the liquid solutions of carbon in iron are homogeneous, because rapidly cooled solid "solutions" are found to be so. He considers that:—(1) Melted cast-iron is a solution of liquid carbon in liquid iron. (2) Grey and soft cast-iron is a solution cooled slowly, and converted into a mixture of mild steel and amorphous carbon or graphite. (3) Grey cast-iron heated cherry-red and plunged into cold water is a mixture of hardened steel and graphite. (4) White cast-iron is a solution cooled rapidly, and consists of a mixture of crystallized carbon in amorphous iron. (5) White cast iron reheated, and while protected from the atmosphere, becomes grey and soft, is grey and soft cast-iron. (6) White cast-iron heated in contact with air, and grey or white iron reheated in closed vessels in a cement of metallic oxide, become mild steel. (7) Steel heated cherry-red is a mixture of liquid carbon in solid iron. (8) Mild steel is a mixture of amorphous carbon in iron, either amorphous or crystallized. (9) Hardened steel is a mixture of crystallized carbon in amorphous iron. He further states that iron absorbs carbon at temperatures ranging from cherry-red to welding heat, and up to a quantity equal to 5.25 per cent. of the mixture; that the properties of steel approach those of iron in inverse proportion to the quantity of carbon; and that the presence of carbon not only increases the fusibility of the alloy but communicates to it, in certain ceses, properties belonging exclusively to crystallyzed carbon or diamond. He also states the temperature of fusion of grey cast iron is higher in proportion as the quantity of graphite is greater, while the temperature of solidification is lower in proportion as the quantity of dissolved carbon in the fluid mass is greater. The lower, therefore, the temperature of solidification of grey cast iron, the higher is its point of fusion; it is only steel that has the same temperature of fusion and solidification. This property of cast iron is common to many bodies, such as bismuth, tin, sulphur and water, under favorable conditions of cooling. Caron states that steel, if hardened by being heated to redness and cooled rapidly, and then dissolved in strong hydrochloric acid, leaves no residue; that the same steel, if raised rapidly to a red heat, and allowed to cool slowly, will, if dissolved as before, leave a residue of carbon, which dissolves on being heated; and that the same hardened steel, if annealed by being kept at a red heat for a long time, and allowed to cool slowly, dissolves more easily, but leaves a residue of carbon insoluble even in hot acid. The conclusion he draws are, that in the first case the iron and carbon are intimately united and dissolve together; in the second case the union is not so intimate, therefore the more soluble body dissolves first, and the carbon, which is not quite modified, yields last; and in the third case the carbon is free, and shows it by its property of resisting acids. What Caron terms a solution of iron or carbon in hydrochloric acid appears to your committee to be probably a "double decomposition." Carbon is very unchangeable, resists the action of acids and alkalies, and bears the most intense heat in close vessels without fusing or undergoing any perceptible change. Baumhauer confirms these statements with respect to diamond, and relates the experiments by which they are proved. He also states that a diamond, when heated for a long time to whiteness in carbonic acid gas, showed prismatic colors on some of its facets. Akerman states that graphite is only mechanically incorporated in pig iron, and can be separated by dissolving the iron in acid. The combined carbon, on the other hand, when the iron is dissolved in boiling hydrochloric acid, escapes as carburetted hydrogen, provided proper attention is given to the dissolving process, so that the boiling commences almost immediately after the addition of the iron to the acid, and is continued uninterruptedly for a sufficient length of time without access of air. When dissolved in cold acids, and warmed a little time after, a part of the combined carbon remains as a black residue, especially if air has ready access. He also quotes Caron's and Rinman's statements with respect to the solution of steel in acid. Gruner states that each temperature corresponds to a maximun of solubility, and that this solubility rises and falls both in the fluid and solid states. Whenever a carburetted iron (steel or cast iron) cools slowly, an intimate mixture of iron and particles of graphite is produced, as in the case of untempered steel and grey cast iron. When carburetted irons are cooled quickly, the separation of carbon is rendered impossible for want of time, and carbon remains dissolved in the iron at ordinary temperatures; saturation then results. The mixture then becomes hardened steel when the proportion of carbon is below 1.5 per cent., and white cast iron when above that quantity.

III.—SUBSTANCES OTHER THAN CARBON ENTERING INTO THE COMPOSITION OF STEEL.

Dr. Siemens is of opinion that high-class steel should contain only iron and carbon: the hardness, temper, ductility, elasticity, toughness and strength depending upon the relative proportion of these elements. But as it is almost impossible to produce such pure metal, other substances, which must, however, be considered as impurities, have to be admitted: these impurities have a certain influence in rendering steel hard, or rather in making it brittle; thus, if phosphorus is allowed, a certain dose of manganese has to be added to prevent cold-shortness, and a smaller quantity of carbon must be used. Manganese is a treacherous element in steel, as its distribution is not uniform, and thus a homogeneous compound is not produced. According to Fernie, a sample of Krupp steel contained 1.18 per cent. of carbon and a trace of manganese, and a sample of American steel 0.23 per cent. of carbon and no manganese; the latter constituted soft metal fit for fire boxes. Fremy (1864) advanced the theory that nitrogen was an essential component of steel; that steel was, in fact, a nitro-carburet of iron. Caron, however, considers it proved that all kinds of iron contain feeble quantities of nitrogen, 0.00011 per cent. and considers that it must be looked upon as an impurity just like silicon, sulphur, and phosphorus. According to F. C. G. Müller, it has been proved that hydrogen, nitrogen, and carbonic oxide are to be found in the pores of Bessemer and Siemens-Martin steel. Cyanogen, tungsten, chromium, platinum, silver and other substances, have been mixed with steel with a view to give it certain high qualities; but Chernoff, Dr. Siemens, and many others are of the opinion that true steel is a mixture or combination of carbon and pure iron alone, and that all other substances are impurities necessarily injurous in pure steel, though sometimes apparently beneficial if they exclude or neutralize more injurious substances. Boman states that Bessemer steel No. 1 (which is necessarily impure), containing only 2 per cent. of carbon, is hardly malleable; while Anosoff found that the hardest "boulat" (the sabre steel of the Tartars), which is perfectly pure, retained its malleability though it contaned 3 per cent. of carbon.

IV.—HARDENING OF STEEL.

Jullien holds that carbon in contact with iron at cherry-red heat becomes liquid, and is absorbed like water in a sponge, like oxygen in liquid silver, or like gas in porous bodies; cooled slowly, the carbon becomes amorphous, and the steel becomes soft as iron; cooled quickly, the carbon crystallizes to depths proportioned to the energy of cooling, and steel becomes diamond set in iron. In your Committee's opinion, this theory, even if it accounts for the hardening of steel, does not account for tempering. What takes place when hardened steel is heated and passes through all the gradations of hardness indicated by their characteristic colors! Jullien quotes Berzelius as stating that when a saline solution, saturated or not, is allowed to cool quickly almost to the congealing point, the periphery which is first cooled becomes less saline than the center; until at last, when the entire mass has solidified, the dissolved salt is found concentrated in the center. From this fact he infers that two bodies dissolving each other, and preserving their independence in solution, must produce solid compounds of varying properties according to the rate at which cooling takes place. Furthermore all solid bodies are susceptible of two different molecular structures, dependent on the rate of cooling from the fluid state; but this rate of cooling does not produce the same results on all. Thus gold, silver, and copper, if cast in chills, yield a fibrous structure, while, if cast in sand moulds, they exhibit a crystalline fracture; and the fibrous structure can be changed into the crystalline by a temperature short of fusion. Carbon and glass behave quite otherwise. Diamond, exposed sufficiently long to a high temperature in a covered crucible, becomes amorphous or graphite: hence it may be concluded that, if it could be taken liquid and subjected to energetic cooling, it would crystallize; while under slow cooling it would become graphite. Glass, taken liquid and submitted to energetic cooling, crystallizes; but when annealed, it becomes amorphous or ceramised. Rupert's drops, which are transparent crystallized glass, become opaque if heated for a long time. He therefore considers that a mixture of iron and carbon, if cooled quickly, becomes hard because the carbon crystallizes into diamond; while, if it is cooled slowly, the carbon remains amorphous and comparatively soft. Chilled grey cast iron has a mottled band between the chilled and unchilled parts; this is the zone where the carbon is partly crystalline and partly amorphous. Gruner considers that carbon is dissolved in hot iron: that when cooled slowly the carbon has time to separate as graphite, but when cooled quickly there is no time for separation; and white chilled iron instead of grey cast iron is the result. Soft and hard steel show a similar difference though to a less degree. Barba and Akerman consider that the compression resulting from rapid cooling is the cause of a greater amount of carbon being retained in solution, and prevented from separating as graphite. Your committee find it difficult to accept this theory, because the compression of the internal portion of a piece of steel is caused by the contraction of the outer layers; and these, therefore, must be stretched, as indeed it is well known that they are. But in hardened steel the outer layers, which were most energetically cooled, are the hardest, although they must have been, and probably are, in a state of tension. Akerman, however, considers that compression, or forcing together of the particles, the amount of which is dependent on the rapidity of cooling, produces hardening; and that the intensity of this hardeneng depends on the compactness of the material and its limit of elasticity. By the way of proof he states that cold-working, rolling, and wire-drawing produce similar results.

V.—THE MOLECULAR CHANGES THAT OCCUR IN HARDENING, TEMPERING AND ANNEALING.

The theory announced by Chernoff in 1868 to the Imperial Russian Technical Society appears to explain in a satisfactory manner the molecular changes that take place in steel when subjected to changes of temperature. His view is that:—(1) There is a certain temperature, *a*, such that steel of whatever quality will not harden if heated to any temperature below *a*, and energetically cooled. (2) There is some higher temperature, *b*, above which steel changes from the crystalline to the amorphous condition. (3) If heated to a temperature between *a* and *b*, steel may harden, but does not change its structure, whether cooled quickly or slowly. (4) If heated above the temperature *b*, and up to the melting point, steel has a wax-like structure, is incompressible, and tends to crystallize into larger crystals if left to cool slowly undisturbed, but into smaller crystals if hammered or if rapidly cooled. Fine grain is essential to good, tough steel; hence, by heating up to the temperature *b*, so as to produce the amorphous condition, and then cooling suddenly to below *a* in oil or water, good steel can be obtained. The temperatures *a* and *b* vary with the nature of the steel. Chernoff illustrates his views by reference to the behavior of alum undergoing crystallization; and the close reasoning of his remarkable paper carries a strong conviction of the correctness of the views he advocates. There are abundant illustrations of his theory to be found in the many writers on steel who have been consulted. Thus Hackney states that quenching mild steel improves its tenacity and ductility. Riley expressed an opinion that it was not so much the percentage of carbon as the way in which the rails had been cooled that should be taken into consideration, when two rails of the same chemical composition differed in hardness. Barba states that annealing should not be done at too high a temperature, otherwise the steel will crystallize with slow cooling, will lose elasticity, and become what is ordinarily called "burned." Caron states that "burned" iron can be restored by raising it to a white heat, and then placing it under the rapid action of a steam hammer. Chernoff also describes and explains the case of a "burned" ingot of steel, which he treated in the above manner and restored to its proper condition. Osborne states that steel has a remarkable property of remaining in a pasty condition through a considerable range of temperature below its melting point; and that bar-iron acquires a largely crystalline structure when exposed for a long time to heat considerably below fusion.

Professor Gore, in 1869, and subsequently Professor Barrett, in 1873, drew attention to certain anomalies that occurred in the expansion and contraction of iron wire: and in 1877 Professor Norris published the results of his experiments on the same subject, which appear to confirm Chernoff's theory in a remarkable manner. In cooling a strained iron wire from redness, it was found that the contraction due to cooling was, at a certain point and for a limited period, changed into an action of elongation. In good iron wire this irregularity could not be detected, but in hard wire and steel it was very apparent. The wire has to be raised to a very high temperature before the temporary elongation during cooling can be seen; and it does not take place if the wire is heated only just beyond the temperature at which it occurs. Professor Norris' researches have led him to the following conclusions:—(1) That in steel, and in iron containing free carbon, there is a contraction or shortening which is excited by heat, and which proceeds simultaneously with the dynamical expansion and masks its true amount. This is divisible into high and low temperature contraction. (2) That similarly there is a cooling expansion or crystallization, which comes in during the dynamical contraction and masks its true amount. (3) That these effects, due to crystallization and decrystallization, are the causes of the so-called "kicks," or temporary contractions and expansions, which occur during the heating and cooling respectively of the steel. (4) That the low-temperature contraction and cooling expansion are due to decrystallization and crystallization, which occur during the acts of heating and cooling; while the "kicks" themselves are simply the thermal effects associated with these changes, and are proportionate to their extent. (5) That protracted annealing, *i. e.*, extremely slow cooling, brings about molecular separation of the carbon and iron. Steel in such a state contracts greatly when high temperatures are reached, producing the effects of contraction which are seen at the ends of the heating, and which are due to the condensation produced by the recombination of the carbon and iron. Steel in this state is less susceptible to cooling-expansion (or crystallization), and therefore to low-temperature contraction on subsequent heating." It would seem that the "kicks" observed by Professor Norris probably occur somewhere in the region of Chernoff's temperatures *a* and *b*, where a change in the molecular structure of steel appears to take place according to his theory. At any rate it is plain that molecular changes of some kind do occur, and manifest themselves by altering the bulk of the metal.

It has already been stated that Müller has demonstrated the presence of hydrogen, nitrogen and carbonic oxide in the pores of Bessemer and Siemens-Martin steel. Edison, at the recent meeting of the American Association for the Advancement of Science at Saratoga, has extended the observations at Döbereiner, St. Clair-Deville, Troost, Faraday and Graham; and has not only applied the facts ascertained to explain the destruction of refractory metals, such as platinum and iridium, under long-continued high temperatures, but has discovered the means of overcoming those defects, which have proved a serious hindrance to the extension of electric lighting, Edison noticed that the effect of incandescence on wires was to produce, all over their surface, innumerable fine cracks. When the incandescence was maintained for twenty minutes these fissures became so enlarged as to be visible to the naked eye; and, when still further continued for several hours, the cracks united and the wires fell to pieces. A number of experiments have led him to the conclusion that the cracking of the surface of the metal is due entirely to the occluded gases, imprisoned within its pores, which become expanded and are driven out under the action of heat. By heating spirals of platinum wire gradually, by means of a transmitted electric current of periodically increasing strength, and within an exhausted chamber, the gaseous substances contained within the metal were gradually withdrawn; and by allowing the metal, in the interval between each increase of temperature, to cool down *in vacuo*, a series of expirations from the surface took place, alternating with a closing up and welding together again of the minute fissures through which the gentle heating *in vacuo* had enabled the gases to escape. By continuing this simple operation it has been found possible to change completely the physical character of metals; increasing their hardness and density to an extraordinary degree, and raising their points of fusion so high that they are perfectly unaffected at temperatures at which most substances would be melted and even volatilized. A spiral or ordinary platinum at a white heat softens and loses its elastic and rigid character; but platinum, after having been treated in the manner above described, becomes as rigid as steel, and as homogeneous as glass; and retains these properties when glowing under the most intense incandescence. The metal so transformed cannot be annealed by any known process.

It appears to the committee that the expulsion of the gases contained in the body of the metals may have the effect of bringing the ultimate atoms closer together, increasing thereby the force of their cohesion, and consequently resisting more strongly any re-arrangement that would be necessary in annealing. It would appear also that the existence of gases in the pores of metals is an attribute of their normal states; and that the expulsion of the gases increases hardness and necessarily raises the melting point on account of the stronger cohesion of the atoms. May it not be that the sudden contraction in hardening steel has the effect of expelling occluded gases; that subsequent tempering, by raising the temperature, has the effect of permitting a fresh absorption; and that the iridescent colors which accompany tempering are due to the change of surface caused by the infiltration of gases? Another view is that the mere heating of steel to the proper temperature for hardening is sufficient to expel a portion of the gases, which are kept out by sudden cooling, and are slowly re-absorbed in tempering. Graham states that platinum at a low red heat will absorb four times its volume of hydrogen, and that palladium condenses more than 600 times its volume of hydrogen at a temperature below that of boiling water. May not steel therefore possess analogous properties with respect to some of the gases constituting the air? May it not absorb these more freely as the temperature of tempering rises, and so gradually becomes restored to its original softness?

VI.—Directions in which further Investigations appear to be needed.

(1) To investigate whether Edison's theory can be applied to the explanation of the hardening and tempering of steel? and to ascertain by experiment whether absorption and expulsion of gases take place. (2) To determine by analysis whether any chemical difference exists between the outer and inner layers of a piece of hardened steel, which before hardening was of homogeneous structure. (3) To ascertain whether there is any connection between Chernoff's theory and Norris' observations on the contraction and expansion of wires.

Novel Gunnery Trial.—Major-General C. W. Younghusband, C. B., Royal Artillery Superintendent of the Royal Gun Factories, Royal Arsenal, Woolwich, has gone to Italy to witness a gunnery trial of a novel and interesting description, the gun being one of 100 tons weight, but made of cast iron instead of the wrought iron or steel, which modern artillerists regard as indispensable for heavy weapons if they are to fire large charges. The strain to which this cast iron piece of ordnance will be subjected is not stated, but the gun is described as strengthened with hoops of steel, and theoretically capable of great endurance.

ENGINEERING PROGRESS DURING THE LAST FIFTY YEARS.

Address of WILLIAM HENRY BARLOW, Esq., F. R. S. President of The Institution of Civil Engineers.

The important rank which The Institution of Civil Engineers has acquired in this country, and the estimation in which it is held by foreign countries, while they are circumstances of which we must all feel proud, necessarily impose upon its members, and especially on those who take a leading part in its affairs, duties of corresponding responsibility.

And in taking the high position of President to which you have elected me, and for which I thank you as being the highest honor my professional brethren can bestow, I feel it to be accompanied by duties of so onerous a character, that I should have hesitated to undertake them, did I not feel that I may rely with confidence on your aid, not only to maintain, but if possible to raise yet more, the high standing which this Institution has already attained.

It becomes my duty this evening to offer to you some observations in the nature of an address, but the variety of subjects which have been so ably treated by my predecessors in office, render this task one of considerable difficulty, and I must claim your indulgence while I endeavor to fulfill it.

Having commenced my professional career in the same year as that in which this Institntion received its Royal Charter, namely 1828, I propose to draw your attention to one or two of the great features of change and progress in engineering which have arisen since that time; because these changes have had a marked and important effect on the conditions under which we live in the present day, as compared with what they were fifty years ago. It is in fact difficult for those who lived at that time to recall all the circumstances of their then daily life, so much have we become habituated to the facilities with which we are now surrounded; and I think it is not claiming too much to say, that some of the most important of those facilities are the direct result of applications of engineering science.

There is one circumstance of my early life which left a strong impression on my mind, and which I may be pardoned for mentioning, namely, the first time I was present at a meeting of this Institution. This was in 1827. I went accompanied by my brother, Mr. P. W. Barlow, who was then an associate, and is now one of our oldest members. There were several men then present whose names are well known to us, among them Mr. Joshua Field, Mr. James Simpson, Mr., now Sir, John Macneill, and Mr. Henry Palmer; but the one who riveted my attention was the great Thomas Telford, who occupied the chair, and who to me seemed as a superior being gifted with higher attributes than ordinary men. It appears by the records of the Institution that the whole number of persons present at that meeting including visitors, was twenty three—and that was considered a well-attended meeting.

Of the large features of change which have appeared since this Institution received its Charter, there are none which have produced so marked an influence on the well-being of this country, and on the world at large, as the improvements in the means of communication, by the application of steam to locomotion on land and in ocean navigation. And as allied to this subject the communication of intelligence by the utilization of some of the powers of electricity.

It is not alone in the economical results, or in the impulse and larger area given to commercial enterprise, that advantage arises, but mutual interests become established between the inhabitants of different countries; people are induced to travel and enlarge their sphere of observation; dwellers in distant places are brought together, and the opportunities for interchange of ideas and thought are increased.

For some time previous to 1828 great urgency had been manifested to improve the means of transport of goods and minerals. The canals, which in this country date from about the year 1758, and estimated in 1836 to exceed 3,000 miles in length, were found inadequate to the wants of the commercial interests at the time in question.

Much attention was bestowed on turn-pike roads, some of the main lines of road communication having been brought to a high degree of perfection under the direction of Telford.

Tramways, which date long before canals, existed in considerable numbers in the mineral producing districts; but they were for the most part of cast iron, and belonged to private owners, few of them being applied to the general purposes of commerce.

There were also some railways, distinguished from tramways, as their name implies, by being formed of rails instead of tram-plates, among which was the well-known Stockton and Darlington Railway.

The application of steam in locomotive engines was in an early experimental stage.

It is needless to mention the name of George Stephenson, and the important part he took in the early establishment of railways. His name will always be associated with railways, not so much on account of the engineering ability he displayed, but because it was due to his strong convictions and his force of character, that the Liverpool and Manchester Railway Company adopted locomotive engines for their tractive power; and the commercial success of this enterprise formed the starting point of that great railway system which now spreads its network and ramifications in many parts of the world.

That the discovery of a better system of locomotion by land was greatly needed, is evinced by the rapidity with which the railway system has spread, and the extent to which it has already been carried.

The Liverpool and Manchester Railway was opened in 1830, and within forty-five years of that time Sir John Hawkshaw, in his address to the British Association, estimated the total length of railways then existing at 160,000 miles, and the capital invested in their construction £3,200 millions.

Since that time (1875) there has been a further considerable extension, and the growth of the railway system continues. And when it is considered that China has at present no railways, and Japan is only beginning, that the whole of Africa, whose population is estimated by Mr. Brassey at between 350 and 400 millions, is almost without railways, as well as a large part of South America and Central Asia, and that many of our colonies are ill provided, it becomes obvious that the railway system must continue to increase as time goes on.

In the United States of America the construction of new lines is actively proceeding, and even in this country, which seems well supplied in proportion to its area and population, the increase proceeds, not so rapidly as it has done, but still it continues.

In the years

		Miles.		£.
1846	the length was	2,765,	the traffic	7,565,569
1854	" " "	8,053,	" "	20,215,724
1862	" " "	11,551,	" "	29,128,558
1870	" " "	15,537,	" "	45,078,143
1878	" " "	17,333,	" "	62,862,674

The traffic receipts exhibit two separate elements of increase, one being due to the increased length of line, and the other to the continuous growth of traffic on lines already opened—a growth which is found to continue even on the oldest lines.

It is not easy to separate these two elements in the traffic returns, but having devoted some pains to the inquiry, it appears that traffic growth, as an average throughout all the lines in the United Kingdom, and taken over the whole period of thirty-two years, is rather more than £100 per mile per annum.

The traffic for the three years ending in 1878 has been almost stationary, but it was preceded by such very large receipts between 1870 and 1874 that at the date of the last annual returns, it was hardly back to its normal condition.

To meet the exigencies of this growth of traffic a total reconstruction of the permanent way, engines, and carriages, has been necessary, as well as extensive additions to stations. The rails first laid down were of wrought iron, 35 lbs. per yard. Those now used on the main lines are of steel, between 80 and 90 lbs. per yard, and on a large part of the principal railways four lines are laid, enabling the fast trains to be separated from those of slower speed, thus increasing very largely the carrying capacity. The engines, originally limited to five tons in weight, and burning coke for fuel, are replaced with others of greatly improved construction, weighing, with their tenders, from fifty to seventy-five tons, and burning the cheaper fuel of coal.

Carriages first made after the pattern of coach-bodies, with three small compartments on four wheels, are now replaced by large commodious vehicles running in two six-wheeled bogie frames, and the Pullman carriage from America, with its drawing-room car and sleeping compartments, has been successfully introduced.

While these improvements have added much to the comfort of railway traveling, a complete system of block-signaling, the employment of continuous brakes, and the interlocking of points and signals, have greatly increased the safety, notwithstanding the higher rate of speed attained and the largely increased number of trains.

It is impossible to speak of railway traveling at this time, without the mind recurring to the late most lamentable accident at the Tay Bridge.

This grave disaster is now the subject of a searching investigation, the results of which will necessarily be looked for with great anxiety.

Should this inquiry reveal, as we may hope it will, the probable cause or causes which have led to these distressing results, it will afford information of the greatest value for future guidance.

Excepting this one unprecedented accident, railway traveling exhibits highly satisfactory results as regards the safety of that mode of traveling—whether considered in reference to the enormous numbers who travel, or the distances accomplished by habitual travelers.

The distance traveled by some of the company's servants is remarkable. Mr. Allport states that some of the older guards of the Midland have traveled 2,000,000 miles, and Mr. Besley mentions two guards on the Great Western, one of whom is estimated to have traveled 2,400,000 miles, and the other 2,500,000 miles, a distance which may be otherwise expressed as more than ten times that of the moon from the earth.

Street tramways, which have long been used in America, are now introduced to a considerable axtent in the principal cities and towns of Europe. They are evidently a great convenience to a large class of the public, but whether from the mode of their construction or from insufficient care in the maintenance of the roads, some of them render the traveling of other carriages along the same lines of roads very unpleasant—a defect which it is hoped may be remedied. Efforts are now being made to introduce tractive force upon them other than horse traction. Among these are a modified form of the locomotive steam engine, the compressed-air engine, and an ingenious arrangement called the fireless engine.

Steam navigation had made some progress in 1828. The number of steam vessels then existing being 344, with an aggregate tonnage of 30,912 tons, showing an average of about 90 tons each. They were chiefly employed in river and coasting traffic.

In the United States of America further progress had been made, the magnificent rivers of that country being among the earliest means developed for internal communication.

At that time all our ships, including war ships, were of timber. With a few exceptions steam had not been introduced into the navy, and it was considered derogatory in the service at that time to be appointed to the command of a steam vessel.

Ocean steam navigation, which now forms the links of communication between distant countries, had not been attempted, and it constitutes another of those geeat achievements due to the application of steam to locomotion.

As the Liverpool and Manchester Railway was the starting point of the railway system, so were the almost simultaneous voyages of the "Sirius" and the "Great Western" in 1838 the starting point of ocean steam navigation. Its commercial success and the extent to which it has been carried are due to improvements which involve a greater range of scientific knowledge than railways, and are the result of deep thought and unremitting perseverance of many of our ablest men.

We are indebted here to the improved knowledge of the forms and lines of ships—a subject so ably treated by our late lamented colleague, Mr. Froude—to the substitution of iron and steel for timber in the construction, whereby ships are made of greater length and strength and carrying capacity, to the greater advantages in propulsion obtained by the screw propeller, and to the improvements in the steam engine, whereby the consumption of fuel has been so largely reduced.

The capital invested in ocean steamships, thougn large, is not of that magnitude required for railways, but it is rapidly increasing, both as regards the number of ships employed and the dimensions and power given to them.

It appears that prior to 1836 the largest ships afloat were between 800 and 900 tons burthen, and about 220 HP. With the exception of the "Great Eastern," which, though grand in its conception, was in advance of the wants of the day, there has been an almost continuous growth in the dimensions and power employed; and there is now in course of construction, and nearly completed, the steamship "Servia," belonging to the Cunard Company, 7,500 tons burthen, 10,000 HP., 500 feet in length, built entirely of Siemens-Martin steel, and calculated for a speed of 17½ knots per hour. The Allan Company is building another great ship of 5,500 tons burthen, also to be entirely of steel. These magnificent ships will, however, be surpassed in magnitude by the war ships now building. The "Inflexible," for the English navy, will be 11,600 tons burthen, 8,000 HP., and carry four 80-ton guns; and the "Italia," for the Italian navy, will be 13,200 tons burthen, 18,000 HP., and carry four 100-ton guns.

The great ocean steamships, combining sailing and steam propulsion, present in their structure, and the various requirements necessary for the speed, regularity and safety with which they are worked, a number of mechanical and scientific applications of high order, every one of which is the result of much study and mental labor. But the ponderous armor-plated turret ships, armed with their powerful artillery, containing steam engines for propulsion, others for turning the turrets, steering, lifting anchors, working hydraulic machinery for moving the guns, and numerous applications of electricity for signaling and firing and electric lighting, constitute as a whole a most surprising combination of science and skill.

In these ships the improvements are of two kinds, one being directed to the ship itself, its structure and its propulsion, the other to performing different functions of manipulation; and as regards these latter, admitting the excellence of each of the individual contrivances, yet there is a point at which their advantage may be overbalanced by their number and complexity.

The extension of navigation has necessitated great increase in docks and harbor works. These works, some of them of great magnitude and cost, are too numerous to describe in detail. They constitute as pecial branch of engineering of a very important character.

Very large extensions of docks have been made in London, Liverpool, Southampton and Hull. New docks have been constructed at Avonmouth and Portishead in connection with Bristol, besides many other like works in different localities.

Among the principal harbor works are those of Portland, Holyhead and Dublin. The progress in harbors, however, does not appear to have proceeded so rapidly as to mect the full requirements of the time.

The number of wrecks annually reported points to the necessity of more harbors of refuge, and there are evidences that the due development of steam navigation in some parts of our coast is impeded by insufficiency of harbors.

This is especially observable in regard to the communication between England and France. The Channel passage, from its extreme discomfort, interferes prejudicially with the proper interchange of traffic between these countries, and has led to many suggestions for its amendment.

It is satisfactory to learn that the French Government is about to improve the harbors on their coast—a movement which we must hope will be followed by a corresponding action on the part of this country.

The steamboat called the "Calais-Douvre" is a praiseworthy and to a certain extent successful attempt to make the best of the existing harbors, and mitigate some of the inconveniences of this short sea passage; but this vessel only runs on summer service, and the greater room and superior accommodation afforded by her is not attainable in the rough winter months.

Canals have ceased to extend in England, to any appreciable degree, since the establishment of the railway system; but they progress in many parts of Europe, where, in conjunction with river navigation, they afford great facilities for trade carried on in small vessels.

The most remarkable work of inland navigation of our time, one which has exercised a great influence on the ocean navigation of the East, is the Suez ship canal—a work which will always render famous the name of its author, M. De Lesseps.

Another work of great influence on the inland navigation trade of Eastern Europe is the deepening of the mouths of the Danube, by Sir Charles Hartley.

There are also two important American works, not yet entirely completed, one being the deepening of the channel between Long Island and the mainland, rendered specially interesting by the extensive blasting operations at Hell Gate; the other is the improvement and deepening of the south channel of the Mississippi, by Mr. Eads. In this work, by the application of comparatively inexpensive means, the channel has been deepened so as to permit the passage of much larger ships to New Orleans.

The communication of public and private intelligence was formerly dependent on the speed at which a man could travel, and, excepting a limited application of the old semaphores, the Government were in like manner restricted in their intelligence department.

The introduction of electricity for the purposes of telegraphy, and more recently for the production of light, and lastly for the transmission of power, is a matter of especial interest, as being one in which the labors of the philosopher, and the discoveries originating in his laboratory, are made directly applicable to the uses and conveniences of man.

As in many other discoveries and new applications of science, the form which the telegraph received to bring it into actual use was preceded by suggestions, showing the conception of the idea. Sir Francis Ronald, as is well known, made a telegraph worked by frictional electricity, of which he published an account in 1823.

A much nearer approach to the needle telegraph was made in an experiment by my late father (Professor Barlow), who used a galvanic battery, and deflected small compass needles placed in different parts along the conducting wire. By this experiment, of which an account appears in the "Edinburgh Philosophical Journal, of 1825," he found that considerable loss of power arose with increase of length, and he was in consequence discouraged from proceeding further than determining some of the laws on which that decrease depended, and also the relative conductivities of different sizes of brass or copper wire. I was present at this experiment, and though only a lad at the time, I well remember that the battery used was the large quantity battery he employed in his experiments on electro-magnetism, that no coil was used, and that the wires were hung to the posts without any insulation.

The form which the telegraph received at the hands of Sir Charles Wheatstone and Sir William Cooke, and its application to signaling on the Blackwall railway in 1838, established its practicability. Through the influence of Mr. Robert Stephenson and Mr. Bidder, a company was formed to work this invention for commercial purposes, and from that time, by the aid of numerous inventions and adaptations, and especially by having overcome the difficulty of crossing the ocean, the system has spread with a rapidity to which there is no parallel.

In 1875, the total lengths of wire in operation was estimated at 400,000 miles. Since that time the Eastern Telegraph Company has extended its lines to the Cape of Good Hope, two new cable lines have been laid by Dr. Siemens between France and America, and large extensions and duplications of land lines have been made.

There are no means of tracing the traffic growth of telegraphy, but by the introduction of the duplex system and the automatic working, together with other most ingenious contrivances, the traffic must have extended in a far greater proportion than the length of wire in operation.

Another application of the telegraph now commencing in this country, and already in considerable use in America is the telephone, first publicly exhibited by Professor Bell at the Philadelphia Exhition in 1876. The power of transmitting the sound of the human voice and its articulation gives a high scientific interest. Its value as a commercial instrument consists in saving the time required to write, transmit and re-write telegrams.

The diminution of power arising from increase of length in the conducting wire, as pointed out by my father in 1825, renders it necessary to re-transmit telegrams at the end of long cables.

On land lines, or in short cables working in connection with land lines, this difficulty is surmounted by relays of power applied at fixed stations, and by employing this ingenious expedient on the Indo-European telegraph, Calcutta has frequently been put into direct communication with London, a distance of 7,000 miles.

We are indebted to Professor Morse for what may be termed an extremely "happy thought," namely, the system called the "dot and dash." It constitutes a species of articulation, which conveys intelligible meaning by the relative intervals of continuance and discontinuance of action. It is applied in telegraphy, both in writing and in conveying messages by sound as well as by sight; and Sir William Thompson has for some time passed urged its adoption, where it would be of the greatest importance to the safety of navigation, namely, as a means of distinguishing between lighthouses.

I fear that I have occupied your time too long on the subject of improved communication, but, excepting printing and the steam engine itself, no applications of physical science appear to have produced such extensive and important effects.

The penny postage, for which the name of Sir Rowland Hill will always be renowned in the annals of this country, could not have existed without the aid of railways. Neither would it have been possible without their aid, combined with that of telegraphs, to circulate over large areas, newspapers at the cost of one penny, containing telegraphic information of events which happened in distant parts of the world on the day of their publication.

The subjects of artillery and armor plates were ably put before you ten years ago in the address of your past President, Mr. Gregory. Since that time the contest between guns and plates, and the unavoidable competition among nations for superiority of armaments had led to gigantic apparatus for attack and defence. As the magnitude and power of guns have increased, changes have been required in the metal employed in their construction. In 1828 the largest guns and mortars were made of cast iron. In the next stage of advancement wrought iron was used. And now that guns of the weight of 80 tons and 100 tons are constructed, the metal employed is steel, which is universal, at least so far as regards its adoption for the interior lining.

The controversial question as to the employment of steel for the whole gun, instead of a lining of steel with an iron covering, and as to breech loading and muzzle loading, together with many other interesting and important inquiries relating to large guns, are now under investigation by a very carefully selected tribunal, and the results of that inquiry are looked forward to with great interest.

Water supply and drainage form a branch of engineering which, as effecting sanitary conditions, is now receiving much attention. Your late President's address having been mainly directed to water supply, it only remains to add that his project for utilizing Lake Thurlmere for the supply of Manchester received the sanction of Parliament last session. Important works of drainage and other improvements have been effected in most of our principal cities and towns.

By the action of the City of London, and at a later period the Metropolitan Board of Works, the condition of the metropolis has been greatly improved and embellished. Old London, Blackfriars, and Westminster bridges, which in 1828 encumbered and obstructed the navigation of the Thames, have been replaced by others affording a much larger water-way. The sewage, which used to deliver its black streams at intervals along both river fronts, has been carried away by the great drainage works of Sir Joseph Bazalgette, to whom we are also indebted for the Thames embankment works. Under his advice, and that of Colonel Hayward, numerous street improvements have been made, and in the new buildings bordering on them, the hand of our architectural brethren is manifest in the greatly improved appearance of the metropolis.

If Vauxhall bridge be taken as representing the boundary between London and its suburbs in a westerly direction, there have been three suburban bridges built, namely, Chelsea bridge, Albert bridge and Wandsworth.

Eastward of Vauxhall, in what may be considered the active metropolitan area, the only additional public communications made across the Thames during the last fifty years are the Lambeth bridge and the Tower Subway, both constructed by Mr. Peter W. Barlow; and Mr. Brunell's foot-bridge, since removed and replaced by the public foot-way in connection with Charing Cross railway bridge. But the extensive increase of the traffic, and the general growth of the eastern and more commercial part of the metropolis, produce such great and increasing difficulties with the traffic of London bridge, that some other road communication to the eastward of that bridge cannot much longer be delayed.

In the more ordinary operations of building, one of the noticeable changes is in forming foundations by iron cylinders or caissons instead of the coffer-dams formerly used. This newer mode of construction was early employed in railway bridges by Sir William Cubitt and Sir Charles Fox and its most extended and most recent example is found in the great bridge across the Tay.

The use of concrete has largely increased with the improved knowledge of cements. Concrete was formerly used chiefly in foundations and backing of walls; but in the large extension of the Victoria Docks by Mr. Meadows Rendel, it has been employed for the entire walls, including their face-work and coping. About 450,000 yards have been used in these works with very successful results.

The employment of hydraulic machines has largely increased, some being used for producing great pressures and moving great weights, others are made of quicker movement, water motors, applicable to cranes, hoisting apparatus, opening lock gates, and many other purposes.

One of the most striking applications of the hydraulic press is that employed by Sir Joseph Whitworth in the compression of molten steel. Those who have witnessed this process will be aware of the enormous difficulties which had to be overcome in subjecting large ingots of molten steel to a pressure amounting to 6 or 7 tons per inch. The pressure thus obtained is kept up continuously for an hour or more, and completely closes up every air space, gas space or other interstice, and thus renders the ingot perfectly solid and sound in all its parts.

By a further application of the hydraulic press at these works, the use of the hammer is dispensed with in large forgings of steel; the red-hot metal is pressed into its required form by arrangements under easy guidance and control. Forging by hydraulic pressure has at least the appearance of being a far superior process to the rough and noisy hammering which accompanies ordinary forging. It is practised in Prussia, as well as in this country; several specimens of the work were exhibited at the Philadelphia Exhibition of 1876.

The employment of gas as a means of illumination, which was only beginning in 1828, has increased in a remarkable degree during the last fifty years. The length of gas mains in the metropolis alone was, at the end of last year, 2,500 miles, employed in supplying all the private consumers, and about 58,000 public lamps for street lighting.

Mr. Harry Chubb informs me that in the year 1878 the quantity of coal decarbonized was 1,715,000 tons, and that besides producing nearly 17,500 million cubic feet of gas, there were residual products sold of the value of £745,000.

The coal used appears to be about four-tenths of a ton per annum per head of the population, and of the gross revenue only five per cent. is derived from street lighting, while 20 per cent., or about four times this amount, arises from the sale of residual products. The remainder, or seventy-five per cent., is from gas to private consumers.

The capital invested in metropolitan gas works is about £12,000,000, and for the whole of the United Kingdom £40,000,000.

The brilliant electric light, for which, in its present form, we are indebted to the discoveries of Faraday, has latterly attracted much public attention. Some attempts were made to utilize this light, when its source was derived from galvanic batteries, in which manner it was first produced by Sir Humphrey Davy; but the more recent electro-dynamic machines have placed lighting by electricity on a totally different footing to that on which it formerly stood.

The exhibitions of this light in this and other principal cities during the last year, and the valuable evidence given in the Report of the Select Committee of last session on Lighting by Electricity, leave no doubt of its applicability to many important purposes. It is, in fact, already established in lighthouses where its intensity and power are of the highest value. In large public buildings, in railway stations, and some large shops, in large open spaces, and for street lighting there are already many examples of its application. Whether it can be divided so cheaply and rendered sufficiently convenient for domestic purposes has yet to be ascertained.

In some of the evidence given before the Select Committee, and in the Report itself, there appears to be some confusion between the intensity of light and its illuminating power. The distinction ought not to be overlooked. The intensity of a light bears the same kind of relation to its illuminating power as the specific gravity of a substance bears to the weight of the substance. Many powerful minds are now directing their attention to electric lighting, and we daily receive evidence of its improvement and advance.

The 20-horse-power-engine put down only last year to work twenty lights in its immediate vicinity on the Thames Embankment, has, by improvements applied since that time, been made to work sixty lights, some of them at a distance of more than a mile and a half measured along the conducting wire.

The latest application of electricity, namely, the transmission of mechanical energy, was suggested by Dr. Siemens, in his address to the Iron and Steel Institute in 1877. The laws which govern the size of conductor, and other features as to its economy as a transmitter, were fully explained at a meeting of this Institution subsequently, and have since received practical confirmation. Sir William Armstrong has availed himself of it for working a circular saw placed at the distance of a mile from the waterfall which supplies the power. The deep-sea sounding line on board the "Faraday" is hoisted by mechanical energy thus transmitted from the engine, and Dr. Verner Siemens has succeeded in obtaining locomotive power sufficient to convey thirty persons by similar means.

It appears that including all sources of loss from converting and reconverting the energy from friction in the machines, and from resistance in the conductor, 50 per cent. of the original power can be realized at a mile distance, and that with adequate provisions against heating, Dr. Siemens' conclusion that it is "no 'dearer' to transmit electromotive power to a greater than to a smaller distance" will be realized.

The application of wrought iron in the superstructure of engineering works commenced with suspension bridges, where the metal is subjected only to tensile action. Its employment in large tubular girders designed to resist rupture by transverse strain, originated with Robert Stephenson, Sir William Fairbairn having carried out the first experiments for him in 1845, and assisted materially with his valuable suggestions.

In the tubular bridge of Conway, and in the subsequent larger work over the Menai Straits, the iron was used in the form of riveted plates, a mode of construction since employed extensively in railway bridges.

Before the completion of these works another step was made in advance by girders of this metal framed together in open work. This description of girder involved problems in determining the amount of stress in each member of the structure, which are specially interesting from the exact manner in which the results can be ascertained, and the several parts proportioned to the work they have to perform. It is to these circumstances, and to the greater proportionate depth which can be given to this class of girder, that its greater economy is attributable.

The improvements effected in the manufacture of steel assume the character of new discoveries, which are tending to revolutionize the whole of our great iron industries.

The Bessemer process, followed by that of Dr. Siemens and Mr. Martin, by producing good steel at a very low rate of cost, has displaced a great deal of the iron formerly used in this country—a movement likely to be accelerated by the more recent labors of Mr. Bell and Messrs. Thomas and Gillchrist, in the dephosphorization of the Cleveland ores.

Besides the advantages which steel has over iron for rails, wheel-tyres, and other purposes where it is exposed to wear, and for structural purposes on account of its superior strength, there is a general gain to the community in the production of steel instead of iron, arising from the smaller demand made upon our coal resourses for its manufacture.

To make a ton of iron, about six tons of coals are required, but to make a ton of steel only three tons are necessary; and as it is stated that nearly 50,000,000 tons of coal are annually consumed in iron and steel works, the saving in coals by the substitution of steel in place of iron has been truly called a "national gain."

The production of modern steel is a subject which I have followed from its commencement with great interest, being early impressed with the importance of introducing a stronger material than wrought iron into engineering structures.

Acting as a member of a committee of engineers who made an extended series of experiments on steel, the results of which showed conclusively its applicability to structural purposes, being aware also that the consideration of the subject had been frequently urged upon the Government by Sir John Hawkshaw, I took the opportunity of having to make an address to the mechanical section of the British Association at Bradford, to bring the whole subject to their notice. The British Association then appointed a committee to confer with the Board of Trade, by whom after much correspondence the question was referred to Sir John Hawkshaw, Colonel Yolland and myself. This resulted in the adoption of a co-efficient for steel of $6\frac{1}{2}$ tons to the inch, that of iron being 5 tons, it being further understood that for steel of high qualities the co-efficient should be raised by agreement to a suitable amount, due precautions being observed in the testing.

It would be superfluous to point out to members of this Institution that in engineering works requiring large spans, where the weight of the structure is large in proportion to the load to be carried, the economy produced by employing steel instead of iron will be in a much greater ratio than the relative strength of those metals.

Two great bridges are now in course of construction, one being a public road bridge between New York and Brooklyn, designed by Roebling, having one span of 1,595 feet; the other is a railway bridge across the Firth of Forth, designed by Sir Thomas Bouch, which will have two spans, each of 1,600 feet. In both these bridges the employment of steel becomes a necessity, because the weight required to make them in iron would render them impossible.

Although we know enough about steel for ordinary structural purposes, there are properties belonging to that material which greatly need further experimental inquiry. Untempered steel is nearly like good iron in two of its characteristics. Firstly, it possesses nearly the same modulus of elasticity; and secondly, the force required to extend it to the limit of its elasticity, or the force at which an appreciable permanent set first appears, is about half that required to produce rupture.

The superior strength of untempered steel over that of good wrought iron is proportionate to the greater range of its elastic action; and the ratio which this greater range of elastic action bears to that of iron varies with different qualities of steel. But the strength of steel may be greatly increased by tempering in oil, a process now in considerable use. There are no experiments to show whether the increase of strength so obtained is due to a still further increase of the elastic range, or to a change in the modulus of elasticity.

Experiments are also wanting to determine what change, if any, arises in the specific gravity of metal when under strain within its limit of elastic action. This information is essential for the correct computation of the strength of cylinders subjected to internal pressure.

Within certain limits the stretching of iron and steel beyond its original elastic limit increases the strength and the range of elastic action. The process of cold rolling is an example of this effect. In the Philadelphia Exhibition a large amount of the shafting for driving the machinery was so made. It presents a highly finished appearance, and is known to increase both the tensile and transverse resistance.

Steel wire, drawn cold, exhibits remarkable strength. The pianoforte wire used by Sir William Thompson, in his deep-sea soundings, bore 149 tons to the inch, with an elastic range equal to $\frac{1}{86}$ part of its length, the result in this case showing about the same modulus as iron, and an increase of strength proportionate to the increased elastic range. It is probable, however, that in this, as in some other cases, the increase of strength is accompanied by a great loss of ductility.

The United States Government have recently had constructed a very powerful and accurate testing machine, capable of exerting tensile and compressive strains of 400 tons. This machine has been especially arranged for the investigation of the mechanical properties of steel.

The great advance in practical knowledge has been accompanied with a marked extension of the knowledge of physical sciences; and within the last ten or fifteen years the educational departments of the country have undergone great changes in this respect. By the recent returns issued by the Science and Art Department of the Committee of Council, it appears that the number of schools in which elementary scientific instruction is given, has increased in eleven years from 212 to 1,297. That the number of students who came up for examination has increased during the last seven years from 18,750 to 40,086, and that the numbers of first classes in elementary and the advanced stages has risen in that interval from 2,431 to 11,488.

Mr. Fowler, in his address in 1866, dwelt at some length on the kind of education best suited for an engineer. Of late years several of our colleges have devoted a special branch of their teaching to engineering classes, and the increasing area of scientific requirements renders it desirable that a yet wider field should be given to that class of instruction. It is obvious that pupils should be made acquainted with the principles which lie at the foundation of engineering science, and with the nature and property of the materials employed before they can enter with advantage upon actual work, which consists in applying those principles and those materials to practical use. The numerous colleges directed to this class of teaching in France, Germany and Switzerland, give to the engineers of those countries some advantages over us in this respect.

It is true that the best teaching will be given in vain to those who do not possess the qualities of mind fitted for their avocation; neither will any preliminary education suffice unless it is accompanied by active observation and subsequent continued self-instruction.

Lord Shaftesbury, in a recent Paper, remarks, "that having given to every one the elements of knowledge, you have given him access to the means of acquiring more;" and he adds, "I am convinced that after all the best education a man gets is that which he gives to himself by his own exertions."

There are many instances where power of observation and self-instruction have enabled men to rise without much other teaching. Young men taken from ordinary schools and placed at once as pupils in the workshop or engineering works, are mainly dependent for their progress on those powers of mind; and what they learn in that way, though laboriously obtained, is rooted and grounded in a manner which probably no other teaching can accomplish. But there can be no doubt that their path would be made easier, and the scope of their observation wider, by previous education specially directed to the class of subject with which they have to deal. So far as my experience extends with regard to pupils, those who have come from colleges where applied science is taught, take at once a higher position, and have a much larger sphere of usefulness than equally clever men who have not had that advantage.

In the early days of this Institution the knowledge of the strength of materials, and the laws which govern mechanical action and forces was very imperfect. We had many theories based on assumed but not always correct data, and we had many valuable experiments upon which useful but empirical rules had been founded. Smeaton, Telford, Rennie, Tredgold, Buffon, Beaufoy, and others contributed much to the knowledge existing at that time.

My father's essay on the strength and stress of timber appeared in 1817. This book went through many editions under the title of Barlow's Strength of Materials. It owed its popularity and success to the great want of systematic information which prevailed at that time, and to the fact that besides containing clear mathematical investigations of the several questions, it also contained concise rules for their application, written in simple language such as any well-educated workman could read and understand.

It is curious to observe that until that work appeared, it was still a disputed point whether the deflection of a beam strained transversely varied as the square or as the cube of the length, Bernouli's investigation giving one result, and Girard's so-called experiments giving another. My father made a totally independent investigation, accompanied with a series of clear and conclusive experiments, and thus put this question at rest for ever.

This fact is one among many which might be cited, showing the necessity of carrying on investigations of this nature, not by theory alone, nor by experiment alone, but by both, so as to check and establish every point of the inquiry.

Professor Rankine, in his address to the Senate of the University of Glasgow in 1855, refers to the antagonism between theory and practice. He attributes its origin to the ancient Greek philosophers who, in regard to physics and mechanics, entertained the fallacious notion of the existence of a double system of laws; one theoretical, discoverable by contemplation and applicable to celestial bodies, the other mechanical, discoverable by experiment and applicable to terrestrial bodies. And he goes on to show how the science of motion founded by Galileo, and perfected by Newton, overthrew this supposition and proved that celestial and terrestrial mechanics are branches of one science.

That some relics of this antagonism are yet to be found is true. There is a class of practical men who reject the adoption of any principles except trial and error. But there are others, and a class daily growing in numbers, who are desirous of availing themselves of theoretical knowledge. Among this class it is not a question of antagonism, but rather want of confidence arising from the existence of theories founded on ideal or insufficient data.

There was, for example, a theory of the arch, of which an account is given by David Gregory, in which it was assumed to be necessary that the line of pressure should coincide with the intrados of the arch. Another by La Hire and Attwood, called the wedge theory, in which it was assumed to be necessary that the pressure should be at right angles to the surfaces of the voussoirs. And it was not until the subject was taken up by Coulomb, and further elucidated by Professor Mosely, that we had a theory based on the conditions existing in a real arch.

Again, in the case of the solid beam strained transversely, Galileo, who, as we are informed by history, had his attention drawn to the subject during a visit to the arsenal and dockyard of Venice, promulgated a theory in 1633 assumed to be dependent on pure mathematical principles. This theory afterwards illustrated by Girard in his "Traité Analytique de la resistance des Solides," is thus commented upon by my father:—"Nothing can be desired more simple than the results obtained by this theory; but, unfortunately, it is founded on hypotheses, which have nothing equivalent to them in nature."

The errors of Galileo's theory were first pointed out by Mariotte, who subjected it to the test of experiment. Then followed Leibnitz, who applied to it Dr. Hook's law of "ut tensio sic vis," but he restricted it to the action of tension, treating the fibres as incompre hensible. Bernouli then took up the question, contending that part of the fibres were compressed and others extended. For some reason, probably because his results did not accord with experiment, he doubted the universal application of Dr. Hook's law. But this law, which is found to be perfectly consistent with experience, when applied to direct tension or direct compression within the limit of elasticity, is again had recourse to by Dr. Robinson, who next follows up the investigation, and by him the subject of the neutral axis is introduced, leaving its position undetermined.

The theory of the beam thus left has proved a misleading theory. Tredgold was misled by it while endeavoring to deduce the tensile strength of cast iron from bars of that metal strained transversely; the computed result giving him a tensile strength of 20 tons per inch, whereas it is only 8 by experiment. My father, who had ascertained the tensile, compressive, and transverse resistances of wrought iron, was misled by this theory into the supposition that the position of the neutral axis rose during strain above the center of gravity of the section.

Subsequent experiments of my own ('Phil. Trans.' 1855), made on large rectangular beams of cast iron and wrought iron, proved by actual measurements that the neutral axis was in the center of gravity of the section, and remained there throughout all the degrees of strain applied.

The subject of the transverse strength of beams has recently been treated in a valuable paper of Mr. Charles Emery, of New York, who suggests certain hypotheses which may lead to an amended theory. But we are still left without any adequate explanation by theorists of those causes which render a solid beam, whether of cast iron, wrought iron, or steel, so much stronger than the present theory of the beam would give it, as deduced from the tensile strengths of those materials.

In looking at the great progress of engineering science during the last half century, it will be observable that some of the most important advances have arisen in this country; among them, the application of steam to locomotion on railways, and in ocean navigation; the employment of wrought iron for ship building and for large girders; the screw propeller, the utilization of the powers of electricity for telegraphs and electric lighting, and the production of modern steel.

But while we seem to possess in a high degree the power of initiating great and practical ideas, other countries are quick in adopting them, and in many cases improving upon them, so that we receive back from them new applications and adaptations of the greatest value, as well as many new and useful inventions of their own.

It is in fact impossible to study the works of our foreign brethren without feeling, not only in regard to the magnitude of some of these undertakings, but also as to the excellence of their execution and the fertility of resource displayed in overcoming local difficulties, that we have now to deal with competitors with whom it will tax our best energies to keep pace; and in the varied conditions encountered in foreign countries, new and modified methods of treatment arise with which it becomes desirable that everybody connected with this Institution should be kept informed.

It is with this object that the Council, ably aided by their Secretary, Mr. Forrest, have, of late years, appended to their printed papers and discussions, extracts from foreign publications containing descriptions of works, and condensed extracts from engineering Papers of foreign countries.

To me it seems of great importance that our engineers, many of whom must look in the future to employment abroad, should be well informed of what is passing in other countries; and though much may be done to supply this information by books, and by the perusal of the valuable engineering periodicals of the day, yet, where practicable, a visit to the engineering works of other countries and an examination of them considered in reference to the resources available for their execution, and a personal acquaintance and interchange of ideas with the engineers themselves, brings with it elements of instruction of the greatest value.

Many of us have the advantage of acquaintance with the more important engineering works in Europe, but there is perhaps no country which presents such varied and extensive information as the United States of America. It became my duty in 1876 to go to America as one of the judges of the Philadelphia Exhibition, and I cannot only speak of the great amount of valuable information to be obtained there, but also of the hearty welcome with which English engineers are received by their American brethren.

American engineers are in advance of those in this country in regard to the application of steel in engineering structures. In Mr. Eads' great bridge at St. Louis of three arched spans, the center opening being 520 feet and the side spans nearly as large, the arches are made of steel. And in a recent large railway bridge, erected at Glasgow, U.S., by General Sooy Smith, the entire structure is of steel. We have also seen by Mr. Clarke's valuable paper on large span iron bridges, read during the session of 1877, how carefully the study of iron open-work girders has of late years been applied in America, and the numerous opportunities which that great country offers for large works of that description.

In endeavoring to put before you some of the results of engineering progress during the last fifty years—results which have come more or less under my own observation—I am well aware how much has been omitted. Irrigation, mining, and numerous improvements in machinery, afford ample topics and examples of the general advance.

Taking Sir John Hawkshaw's estimate in 1875 as a basis, adding the probable cost of steamships, and allowing for the extension of railways, telegraphs, docks, harbors, and other works since that time, the total capital invested in engineering works cannot have been less than 3,500 millions, or about 70 millions annually; of which about $\frac{19}{20}$ appear to belong to railways, steamships, docks, harbors and telegraphs, all of which are directed to improving and extending the means of transport for passengers and merchandise and the communication of intelligence.

It is observable also that this great progress, which probably exceeds that of any like period in the history of the world, is due to improvements, new ap plications and discoveries, which are the result of experimental research and greater knowledge of natural laws. Beginning with some ascertained scientific fact as the power of steam or the transmission of motion by electricity, the advance made by one man becomes the starting point of another; and thus step by step we have been led up to the point at which we have now arrived, and past which we are traveling rapidly to further developments in the future. Thus railways, telegraphs, steam navigation, and other large achievements, in the advanced form in which we now find them, can neither of them be assigned to the credit of any one man, but they represent the cumulative result of the genius and perseverance of numerous individuals.

This Institution is justified in regarding with satisfaction the number of contributors to this advance who are found among its present and past members; and if there is any one class more than another to whom we stand indebted, it is to those men, both within and without the profession, in foreign countries as well as in our own, who by study and experimental research are continually adding to our knowledge of the powers of nature; those powers, the application of which to the uses and conveniences of man constitutes a fundamental element of the Charter of this Institution.

DYNAMO-ELECTRIC MACHINES.

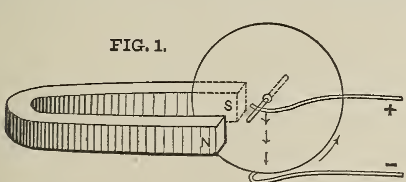
From "Engineering."

I.

Monsieur Antoine Breguet, of the well-known Parisian firm of telegraph engineers, has recently published a series of very important researches on the theory of the Gramme machine and other forms of dynamo-electric and magneto-electric generators, in the course of which he arrives at some extremely interesting results, and clears up a number of points which hitherto have been comparatively obscure in the operation of such machines. Starting from first principles and the simplest experimental data, M. Breguet propounds the successive steps of a logical chain of reasoning to link the grand discovery by Faraday of megneto electric induction with the applications of the principle in the machines of Gramme and Siemens. He is thus enabled to explain a point hitherto supposed irreconcilable with theory, namely, the practice of electrical engineers in setting the "brushes" or collectors of the current in the dynamo-electric machines in an oblique position against the commutator, and unsymmetrical with respect to the field magnets of the instruments. He not only explains this, but points out that it is an absolute necessity of the case, and that upon this position will depend whether the machine is better suited to be a generator or an electro motor. He further explains for the first time the real *rôle* played by the ring of iron in the armature of the Gramme machine. And lastly he elucidates the action of the Siemens machine, and shows that there is at least one method of winding the wires upon its armature superior to that adopted hitherto in practice. It is proposed to treat in the present article of the earlier and more general portions of M. Breguet's research, reserving an account of his work on the Gramme machine and on the Siemens machine for subsequent occasions.

The first principle laid down by M. Breguet is the essential *reversibility* of the Gramme and all other dynamo and magneto-electric machines. Rotated by mechanical means, they supply a current of electricity derived from the energy of a steam engine or other motor. But if you supply them with a current of electricity they will, conversely, rotate and turn the electricity back into mechanical energy. The same thing is true of all electro-magnetic engines or electro-motors, such as those of Ritchie, Page and Froment. They are intended to rotate by electricity, but if you rotate them by mechanical means they will furnish in turn a current of electricity.

FIG. 1.



This principle of reversibility extends even to some unsuspected cases. Very early on in the history of magnetism, Barlow found that he could cause a wheel or disc of copper to rotate between the poles of a magnet, by sending a current at the same time perpendicularly through the disc from the axis to the circumference, where it passed into a pool of mercury arranged to make electric contact with as little friction as possible (Fig. 1). In 1831 Faraday performed the converse experiment, and found that by mechanically rotating a copper disc between the poles of a magnet, he thereby generated a current in a wire, the two ends of which touched the circumference and the axis of the wheel which were amalgamated over with mercury so as to insure better contact with the wire (Fig. 2). Here then is the simplest kind of electro-motor and dynamo-electric generator, and it illustrates at the outset the important principle of

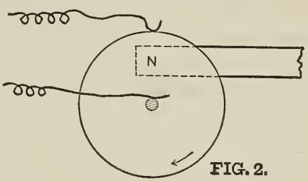


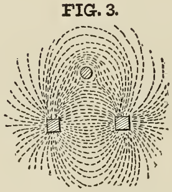
FIG. 2.

reversibility. The second matter which claims notice is the mutual interaction of a magnet and a conductor which carries a current. We sometimes speak loosely of the displacement of a current caused by a magnet when we mean that the conductor carrying the current is displaced. Although the term is convenient, it is scarcely accurate; for we must distinguish between mechanical force, or that which tends to move matter, and electro-motive force (so-called), which tends only to move electricity in a conductor. The mechanical reactions between magnets and current conductors which turn machines are obviously of the former class. These reactions, therefore, deserve to be studied from a nearer point of view, by applying a principle enunciated by Faraday concerning magnetic attractions, and lately further extended by Professor S. Thompson, to the case of the attractions between currents. Faraday first recognized the significance of the so-called lines of magnetic force, which are seen crossing in curves through every magnetic field when iron filings are sprinkled over it. Without necessarily attributing to these lines any physical existence, we may conveniently employ them as Faraday did, to investigate and to describe the actions between magnets or magnetic bodies. Faraday laid down the following properties as those possessed by these lines of force: Firstly, the lines of force tend to shorten themselves.

Secondly, lines of force lying in the same direction side by side repel one another. To these M. Breguet adds that a line of force, when it passes through iron or other metal capable of magnetic susceptibility, must be regarded as if shorter than one of equal actual length passing through air, so that the "tendency to shorten" may exhibit itself by a tendency to run through a magnetic substance near at hand.

By means of these simple principles Faraday was able to deduce the laws of magnetic attraction and repulsion from the figures formed by the lines of iron filings, when sprinkled over the magnetic field whose properties were thus to be investigated. Professor Thompson applied the same reasonings to the case of the attractions and repulsions exerted between two currents, and between a current and a magnet—in a research of which we gave some account to the readers of *Engineering* a few months ago.

FIG. 3.



One of the figures obtained by Professor Thompson (*vide* Fig. 3) enables us to study the action of Barlow's wheel; and this figure M. Breguet takes as the basis of his theory of the dynamo-electric machines. The two square spots show the poles of the magnet, and a point a little way from them represents a metallic conductor perpendicular to the plane of the figure, and traversed by a current which passes downwards through the round spot. This current produces a magnetic "field" all round it, which if the magnet were not present would consist of lines of force disposed in concentric circles. But in presence of the magnet and its radiating lines of force there is a mutual reaction, the nature of which can be learned by simply looking at the figure formed by the iron filings. The tendency of the lines to shorten would assuredly urge the conductor towards the poles of the magnet: and in Barlow's wheel, where this goes on continually in the part of the disc lying between the axle and the mercury cup, the simple attraction becomes a movement of rotation. A current passing in the opposite direction through the wire would obviously be urged in the contrary direction, or away from the magnet. Conversely, if the conductor were mechanically moved further away from the magnet, a current would be generated of opposite direction to that which caused the motion, the electromotive force of the current being proportional to the number of lines cut by the conductor in a second of time.

Following M. Breguet we next pass to a consideration of the first and simplest of electro-motors, as shown in Fig. 4.

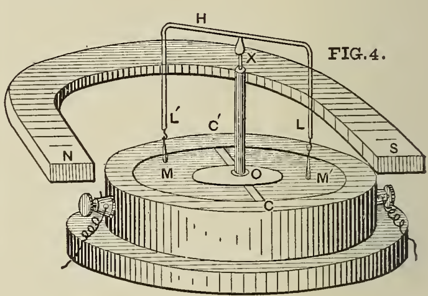
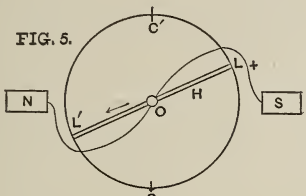


FIG. 4.

This apparatus consists of a metallic conductor bent twice at right angles and balanced on a center at a point X. The vertical branches carry little metallic jointed appendages which dip into the halves of a circular mercury cup divided across by a diametral partition into two portions connected respectively with the poles of a battery; and the whole is placed between the poles N S of a magnet, so placed that the line joining the two poles is at right angles to the diametral line. The conductor rotates upon its center so long as the current passes. We may consider separately the action of the magnet on the two vertical portions L L' and on the horizontal portion H. The action upon the two vertical portions of the conductor is best studied by taking a plan of the apparatus, as shown in Fig. 5, which gives in diagrammatic outline all the working parts. The arrow indicates the direction of the current, which therefore ascends at L and descends at L'. Comparison between the conditions which here exist, and those which gave the magnetic figure, Fig. 3, with iron filings will show a series of lines of force, of which the most characteristic will be the S-shaped curve shown by the dotted lines. Hence the tendency will be to displace L^I towards the top of the figure and L towards the bottom, and their positions of equilibrium will be respectively C^I and

FIG. 5.



C. But if the inertia of movement carry the contact breakers past these points and make them touch the opposite mercury cups, the current will be reversed, L being drawn towards C^I and L^I towards C. Hence there will be a continuous rotation, the direction of the current in the conductor being reversed at every half revolution, when the moving wire passes through the position of equilibrium at CC^I. A little consideration will show that the action upon the horizontal portion H is similar, and adds itself to the forces producing rotation.

Now suppose that instead of the simple wire bent twice at right angles, a conductor be taken having the vertical branches prolonged into two arcs, and carrying, as in Fig. 6, four little jointed

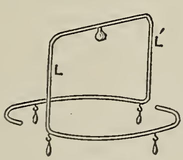


FIG. 6.

contact pieces. We shall now require the mercurial cups to extend over 90° of arc, *i.e.*, extending from C^I only as far as S, and from C only as far as N. Had we taken eight little contact pieces, each mercury cup need only have occupied one-eighth of the circle or 45° of arc. If the number were indefinitely increased, then the arcs subtended by the mercurial contact cup might be diminished by the mere points C^IC. These considerations hold equally good in the converse cases where the instrument is used as a generator of currents.

One further step remains to be considered before we pass on to the application of these matters to the Gramme machine. Instead of the single wire we may take a wire coiled upon a frame, as in Fig. 7, and having many turns. On each wire of this coil there will be a similar action, hence the total force of rotation will be proportionately greater when an equal current is used. In all the various arrangements hereafter to be described, every single wire may be considered in a similar way to represent a coil, and hence the figures may be made as simple as possible. It will be noticed that the single flat coil of Fig. 7 if wound upon an iron spindle and frame virtually constitutes an armature of the type introduced by Siemens, and applied by him in the early magneto-electric machines, and also recently employed by M. Marcel Déprez in the excellent little electro-motors which he has constructed.

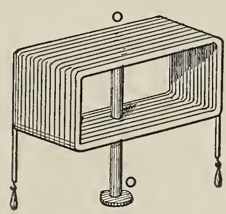


FIG. 7.

M. Breguet starts from two simple principles, viz: that every dynamo-electric machine or generator can be used as an electro motor or electric engine, and *vice versa*; and that a study of the distribution of the lines of force in their magnetic field will enable us to determine the best conditions for the action of such machines and motors.

We have now to pass on to a consideration of one of the very interesting applications which M. Breguet has made of his theory to the study of the Siemens dynamo-electric generator. This machine, which is familiar to the readers of *Engineering* from the article which we published upon it on a recent occasion, is the joint invention of Dr. Werner Siemens and of Herr Hefner von Alteneck. The special feature in it, the armature, with its peculiarly wound coils, of which we shall presently speak, is due to the genius of the latter gentleman, and is in consequence sometimes spoken of as "Alteneck's armature," to distinguish it from the earlier and simpler longitudinal armature with cross-section like a double headed T, employed in the older Siemens machines.

Not to anticipate, however, we must return to the logical order of development pursued by M. Breguet; and must refer at the outset to the very simple machine figured (Fig. 4), in which a single wire bent twice at right angles is made to rotate electro-magnetically between the poles of a horseshoe magnet. A current enters this wire by a mercury cup at one side, and leaves it by a similar cup at the other; the direction of the current through the wire being automatically reversed at every half revolution as the wire swings round, thus alternately attracting up the wire towards the pole of the magnet and repelling it as it passes away on its circular path.

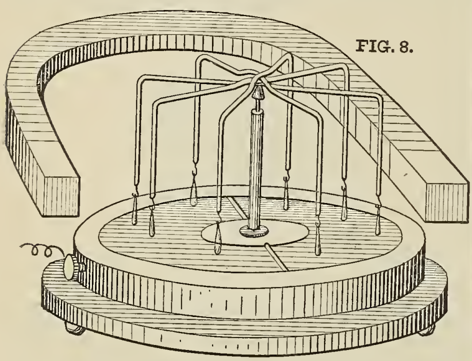


FIG. 8.

Suppose next that four such wires are suspended around the same pivot, and disposed so as to make equal angles with one another, each extremity of each wire being provided as before with a small contact-piece (Fig. 8). What are now the conditions of rotation? A little consideration will show us that if the mercury cups extend as before, and as in Fig. 9, to 180° on each side, the arrangement will be in every way inferior to the one formerly considered; for the current is now shared between four conductors, in each of which there will be but one-quarter of the total current, and they cannot all be situated in the most advantageous position of the field where the attraction or repulsion of the magnet is the greatest. Moreover, some of them will positively be pulled forward while others are pulled backward. So though the current is just as strong as before, the altered distribution of the current is wholly disadvantageous, and the apparatus is both worse and heavier than before. Suppose, however, that the mercury cups are diminished till they subtend, as in Fig. 10, angles of but 90°, only two of the conductors can dip simultaneously into the cup, and one will enter it just as another leaves it. Hence half the current will now traverse each; and if the sectorial mercury cups are judiciously placed so that their edge of first contact lies along CC′, which we may call the "diameter of commutation," at right angles to the line joining the magnet poles, the two conductors in contact can never be far from the point where the attractive force of the magnet field will have the largest effective leverage upon them. Better still will the machine be if the mercurial sectors are still further diminished, as in Fig. 11, down to 45°. Now only one conductor can dip in at once,

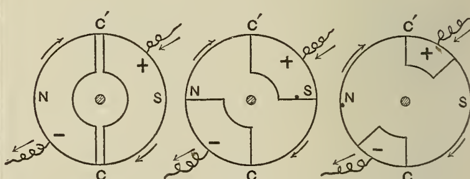


FIG. 9. FIG. 10. FIG. 11.

but it will take the whole current, and as it passes out of contact the next will pass in. The increased weight of the fourfold conductor over the single bent wire of the first arrangement is more than compensated for by the advantage of always having in the most advantageous part of the field that conductor which is being acted upon. Instead of simply receiving an impulse once every half turn, the impulses come eight times during every revolution, and the rotation will therefore be much more uniform.

Once more let us remember what was pointed out in a former paragraph, namely, that every single wire we have considered may be replaced by a coil of many strands, and we shall realize the advance now made towards an efficient electro-motor.

Here, also, we may pause to note that

if by the principle of reversibility we use mechanical power to rotate this system of conductors (or "armature" as we may call it), as it lies in the magnetic field, we shall obtain induced currents. And this new generator will possess corresponding advantages over the simpler arrangement that had only one bent wire, inasmuch as it will give both a stronger and a steadier supply of electricity; there being now eight successive currents generated during one revolution instead of two as before, and these currents will be more powerful, since the conductors in which they are generated are being moved through the most advantageous region of the field.

It is of course unnecessary to suppose the contacts to be made by cups of mercury, except that for light experimental bits of apparatus, the freedom from friction thus gained is of service. If the eight ends of these wires were brought down and soldered to a metallic collar on the axis, the collar being slit into eight separate parts, each of which successively came into contact with metallic brushes occupying the position relatively of the sectorial mercury cups, the same end would be attained, though with a little increased friction. With a larger number of conducting wires, the number of segments of the metallic collar or commutator would be increased, and their angular width proportionally diminished. This is in fact the kind of "commutator" which is used upon almost all the dynamo-electric generators in use.

The recent announcement that the diamond has been artificially produced will doubtless call forth many interesting historical sketches relating to earlier labors in this direction.

Not the least important among these will be the forthcoming memoir of Samuel Brown the chemist, compiled by his brother John Croumbie Brown, LL.D.

As early as 1837 the young experimenter, being then only 20 years of age, began original researches in chemistry, and directed his efforts towards the crystallization of carbon.

Some of the results obtained are described in another place in the present issue. His labors, which ended at his death, in 1856, were largely in the direction of establishing the identity between carbon and silicon.

This memoir will prove a valuable bit of history if it should prove that a method, by means of which success has been reaped now, was employed with similar success some years ago.

To establish an identity between carbon and silicon is of course a problem of another kind, and one which is regarded by scientists generally as of impossible solution.

These allotropic forms of both elements are described in common textbooks, and a general parallelism in physical properties is well known. But any approach to identity between the like forms has been regarded as impossible as any transmutation of the metals.

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia.—The last number of the Proceedings contains the following papers:

XVIII. On Ganguillet and Kutter's Formula for the Flow of Water, by Thomas M. Cleeman.

Discussion of Paper XIV: Proper amount of Water-Way for Culverts, by Thos. M. Cleeman, Chas. G. Darrach, Rudolph Hering.

XIX. Progress of the Geodetic Survey of Penna, by Prof. L. M. Haupt.

XX. On an Important Legal Decision, by Percival Roberts, Jr.

Discussion on Paper XV: On the Connecting Rod, by Prof. Wm. D. Marks.

At the February meeting a paper was read on

The Light House System of the Delaware River from the head of the Bay to Philadelphia, by Mr. Edward Parrish.

The Boston Society of Civil Engineers.—The late papers before this society have been:

The Production and Transmission of Power by means of Electricity, by Geo. W. Blodgett.

Rock Blasting and Machine Drilling, by Wm. Whittaker.

Some Difficulties Encountered in Sinking a Shaft for the Second Lake Tunnel at Chicago, by Eliot C. Clarke.

IRON AND STEEL NOTES.

On Hardening Iron and Steel: Its Causes and Effects.—Knowledge of the effects of hardening, especially on iron, by no means complete, acquired increased interest through the Paris Exhibition, and from the Terrenoire exhibit of Siemens-Martin castings of extraordinary strength, and freedom from blowholes. At the meeting in Paris, Mr. Ackerman gave expression to the view that the reason why the strength of undrawn Martin castings might be equal to that of drawn ingot metal of the same hardness, must be sought in the compression induced by the hardening. The present paper develops that view.

Different Modes of Occurrence of Carbon in Iron.—Commonly the carbon in iron is in two principal varieties—graphite and combined carbon—called dissolved or amorphous carbon. The graphite in iron is carbon mechanically incorporated with the iron. Combined carbon, when the iron is dissolved in boiling hydrochloric acid, escapes as carburetted hydrogen. If the iron, again, be dissolved in cold hydrochloric acid, a part of the combined carbon generally remains as a black residue. The quantity of carbon remaining undissolved when steel is dissolved in cold hydrochloric acid may be very different, according as the same steel was differently treated before dissolving. Raw steel undrawn gives a much larger residue of undissolved carbon than the same steel when rolled, and the latter more than when it is drawn out under the hammer. Finally, this residue of carbon is least to none at all in the well-hardened steel. If this well-hardened steel be heated anew it yields again a large residue of undissolved carbon, and this in a degree proportioned to the duration and intensity of the heating. These facts indicate that the so-called combined carbon does not occur in the iron always in the same way, and that drawing and hardening cause a more intimate union between the iron and the carbon; this union, on the other hand, being again relaxed by the renewed heating and subsequent slow cooling of the iron. It thus appears that the carbon commonly called combined ought properly to be divided into two kinds, viz., first, the carbon most intimately combined with the iron, which we, in accordance with Rinman's proposal, shall call hardening carbon, inasmuch as it characterizes the well-hardened steel; and, further, the carbon incompletely combined with the iron, which may be said to be in a sort of passage to graphite, and which Rinman called cement carbon, because it occurs in largest proportion in the undrawn raw or cement steel. It appears that the cement carbon is changed into the hardening carbon by heating to a red heat succeeded by a violent forcing together, continued until cooling is almost complete; while hardening carbon is changed into cement carbon by long-continued heating followed by slow cooling without extra compression. In the case of strong hardening of hard steel, we have the most powerful compression, for the rapid cooling produces a great difference of temperature between the outer and the inner layers of the piece, the more cooled exterior layers compressing the interior with greater force in proportion, partly as the latter are expanded by being more strongly heated, and partly as the limit of elasticity of the substance is high, so that there is not too great a loss of the compressing force by the extension of the exterior layers. Again, that hammering favors the conversion of cement carbon into hardening carbon, or the more intimate union of the carbon with the iron in which it occurs, more than rolling, may at least occasionally to some extent be attributed to the more powerful compression exerted by the hammer, but still more to the circumstance that the iron or steel, when the rolling is ended, commonly has a far higher temperature than when it has been drawn out under the hammer. For if the iron or steel be still red hot when the drawing is finished, a part of the carbon converted into hardening carbon, or more intimately united with the iron during the compression to which it has been subjected, may be again changed into cement carbon during the succeeding slow cooling. There is thus a very complete correspondence between the occurrence of hardening and cement carbon and their mutual conversion in malleable iron and steel on the one side, and the relations of the combined carbon and the graphite in pig iron on the other. It is not improbable that combined carbon may occur in pig iron also in two ways. A grey but not too siliceous pig may be converted into white pig iron by melting, followed by sufficiently rapid cooling. On the other hand, a white pig, somewhat rich in carbon, but not containing too much manganese or sulphur, may, by melting and superheating, followed by casting in a heated mould which cools with sufficient slowness, be converted into grey pig iron. But in order to change to grey a white pig of the nature described above, it is quite unnecessary to remelt it; for the greater part of its combined carbon may also be converted into graphite by a sufficiently long continued heating to a strong yellow heat, air and other oxidizing substances being excluded. Graphite, as such, cannot be found in the molten pig, for it must then, in consequence of its comparatively low specific gravity, rise to the surface of the iron, and form a deposit there; but in such a case this graphite is found not in, but upon, the pig iron. It thus follows that the graphite to be found in the solidified pig iron has not been able to separate itself sooner than immediately after solidification, and whether a pig becomes grey or white depends, besides the presence of other substances in the iron, just upon the rapidity of cooling at or immediately after solidification. This again depends on the degree of superheating of the pig iron, for the more superheated the pig iron then was, so much more heat has the mould been able to take up before solidification commences, and the slower consequently is the succeeding cooling. Thus also it is only by a long-continued heating to a temperature approaching somewhat closely to the melting point of pig iron that the white pig may, without re-melting, be converted into gray; but if the temperature be raised still further, so that fusion commences, the graphite which has been separated from the iron is again dissolved in it. On this must depend the fact that the fusion point of the grey pig is only about 100 deg. C. higher than that of the white, and thus so incomparably lower than the fusion point of steel or malleable iron, which have the grey pig's content of combined carbon, but altogether want its graphite. As in pig iron, with strong and long-continued heating, carbon is separated in the form of graphite, so heating, followed by slow cooling, favors the formation of cement carbon in steel.

As the cement carbon cannot be so intimately combined with the iron as the hardening carbon, but approaches in some degree to graphite, the supposition is easily arrived at, that the cement carbon cannot have so great an influence on the properties of iron as the hardening carbon; but until hardening and cement carbon can with certainty be distinguished, and some method has been discovered of quantitatively determining each of them, it is, of course, still too early to say anything with certainty on this point. In the near future we shall probably see that some of the great changes in iron and steel which have been induced only by different methods of treating the same material, are caused by the alterations in the proportions between hardening and cement carbon brought about by the method of working.

Consolidation of Fluid Steel.—This paper, by Mr. A. Davis, commenced by a brief notice of what has been done in compressing fluid steel by Bessemer, Whitworth and others. and then described the system of Mr. H. R. Jones, of the Edgar Thompson Steel Company, U.S.A., now in constant operation at the works of that company near Pittsburg. The process is very inexpensive, and consists in simply admitting steam at a high pressure to the top of the ingot mould immediately after the metal has been poured. A steam drum or receiver, communicating direct with the boiler, is fixed, for the sake of convenience, to the side of the ingot crane. This drum has a number of cocks, corresponding with the number of the moulds. India-rubber pipes are provided to conduct the steam, one end of the tube being permanently fixed to the drum, and the other by means of a coupling attached to the lid of the mould. The ingot mould has, at the upper end, a cone seat accurately turned, upon which the pouring cup rests, and which afterwards receives the lid, which is secured in position by means of a steel wedge. By this arrangement the cup is easily removed, and the lid—with coupling and flexible pipe attached—substituted, the cone seat forming a steam-tight joint. In practice a greater pressure than from 80 lbs. to 150 lbs. has not, Mr. Davis says, appeared to be necessary, the higher pressure being used for mild steels. Formerly at the Edgar Thompson Works, with a 14-in. ingot reduced to a bloom of $7\frac{1}{4}$ in. + $7\frac{1}{4}$ in., it was necessary to cut off from 30 in. to 36 in. (*sic*) of the bloom in order to arrive at a part free from piping, whilst under this process the ingots are free from porosity, and are turned out with a perfectly level top. Experiments made in order to ascertain the difference between an ignot cast in the ordinary way and one under pressure, have, it is stated, shown that the latter with the same quantity of metal from the ladle is from $1\frac{1}{2}$ in. to 2 in. shorter than the former when cold. In addition to the consolidation of the ingot, the steam, acting upon the end, cools and hermetically seals the top of the ingot, saves the use of the sand or iron cap, and enables the men to deal with it ten minutes earlier without any fear of bleeding; and this allows the ingot to be conveyed to the reheating furnace with greater rapidity and in a hotter condition than formerly. It is also found that with the use of steam the ingot moulds last better, the average in 1879 being 95 ingots, or nearly 112 tons of steel per mould. The method of compression described in this paper has recently been adopted at the works of Messrs. Bolckow, Vaughan & Co.

RAILWAY NOTES.

The Berlin correspondent of the *Standard* says that the Russian Government have been, and are, actually petitioning at Constantinople for a Bagdad railway concession. They have already been permitted to send out engineers to trace the route. Should they succeed in obtaining a final concession, it will be nominally given to General Tchernaieff. Besides this railway, several others are petitioned for by European speculators at Constantinople. A French company, acting in concert with some of the more strictly Romanist Bishops, is desirous to construct a line from Jaffa to Jerusalem. Russia has offered to connect Kars with Erzeroum in the interest of the White Czar. Englishmen have repeatedly advocated the scheme of a line proceeding from Alexandretto to Aleppo and Bagdad. Last, not least, General Klapka wishes to extend the Constantinople—or rather the Hyder Pacha and Ismid line—to Koniah Bagdad and the Persian Gulf. Without asking any pecuniary assistance, M. Klapka, to cover expense, insists upon all adjoining land being handed over to his company gratis. This condition the Turkish Government are willing to accord, provided nine-tenths of the soil so ceded are handed over to Mussulman colonists, and an agreement can be effected with Mr. Hansom concerning the Hyder Pacha and Ismid line. The difficulties in the way of such an arrangement have given French capitalists an opportunity for likewise putting themselves in communication with Mr. Hansom. What with the competing companies in the field, and the obstruction caused by the recent accession of a Russophil Cabinet at Constantinople, all these various schemes are still in abeyance.

In a recent paper read before the London Association of Foremen Engineers by Mr. M. Reynolds, on practical engine driving, the author spoke of the blinding effect of the glowing white light of the engine fire, a brief glance into which, he said, rendered the person who looked for a time unable to recognize the colors of the signal lamps.

It is now proposed to construct a railway by the Jarentaire and through the Col du Mont, instead of through Mont Blanc, by which it is computed that a saving of seven kilometres might be effected. The promoters, however, seem to forget that the object of a third Alpine railway is to compete with the Gothard line and retain for France the Anglo-Indian traffic ; but from Calais to Brindisi the distance by Mont Blanc is 22 kilometers greater than by Mont Cenis, and exceeds by 160 kilometers the distance between Ostend and Brindisi by the Gothard.

Of the 346 axles which failed the first nine months of the current year, 178 were engine axles, viz., 164 crank or driving, and 14 leading or trailing; 16 were tender axles, 2 were carriage axles, 143 were wagon axles, and 7 were axles of salt-vans. 58 wagons, including the salt-vans, belonged to owners other than the railway companies. Of the 164 crank or driving axles, 124 were made of iron, and 40 of steel. The average mileage of 111 iron axles was 185,629 miles, and of 37 steel axles 153,608 miles. Of the 1,377 rails which broke, 1,258 were double-headed, 93 were single-headed, 12 were of the bridge pattern, and 13 were of Vignoles' section; whilst the section of 1 was not stated; of the double-headed rails, 785 have been turned: 1,168 rails were made of iron, and 209 of steel.

In writing of the new fast train of the Paris, Lyons, and Mediterranean Company, the *Kölnische Zeitung* gives figures to show that the speed of this new express is not, as asserted, the greatest attained on the Continent, but is exceeded by that of several German trains. The Paris-Marseilles express makes on an average 66.3 kilometers an hour, or, including the stoppages, 56.2 kilometers. On the Lelviter line, between Berlin and Cologne, the distance of 583.2 kilometers is completed in nine hours 26 minutes, at a mean speed per hour, including stoppages, of 60 kilometers. Between Spandau and Stendal the mean speed is 71.8 kilometers per hour. On the Potsdam line, between Berlin and Magdeburg, a distance of 142 kilometers is traversed in 2 hours 7 minutes, including stoppages, at a mean speed of 67.9 kilometers per hour. The velocity attained on this line between Brandenburg and Magdeburg, a distance of 80.7 kilometers, is 69.15 kilometers per hour.

ENGINEERING STRUCTURES.

Great progress continues to be made with the St. Gothard tunnel. Three thousand workmen are engaged between Fluchen and Goeschenen, and sixty boarding and lodging-houses have been constructed for their accommodation. Next year 5,000 men will be gathered together in the same district, and a hospital has been specially erected at Wasen, supported to a large extent, like that at Altorf, by contributions from the *employés* themselves. Ten thousand kilogs. of dynamite are used every month at the works, and double that quantity of lime and cement every day.

A Portuguese gentleman has just submitted to the Government a scheme for embanking the Tagus twelve miles above Abrantes, so as to raise it to a sufficient level for being canalized and irrigating about 400,000 hectares of land on the banks. These branch canals would be several hundred kilometers in length, and the cost would be very moderate considering the enhanced value of the land, which he estimates at £24,000,000, or nearly one-third of the National Debt. The scheme and drafts are offered as an act of patriotism, without idea of remuneration, and the Government, it is thought, will refer them for full examination to Portuguese engineers.

The Simplon Tunnel.—Our French neighbors, recognizing the vast importance of the proposed Simplon tunnel to their commerce, have, during the last few months, been in negotiation with the Swiss Government, and a treaty similar to the one which was concluded in 1871 between Germany, Switzerland, and Italy, concerning the St. Gothard tunnel, will shortly be signed, by which permission will be granted to the French Government to subsidize the Simplon Railway Company to the amount of some 48,000,000f. M. Leon Say, the French Minister of Finance, arrived at Vevey on the 16th inst. to make a personal inspection of the site of the tunnel and of the works which have already been carried out, in order that he may possess full *connaissance de cause* in recommending his Government to grant the subsidy in question. The works alluded to consist of a line of railway lately completed and opened to traffic, which extends from Lausanne up the Rhone Valley to Brigue, at the foot of the Simplon—the very spot where it is proposed to pierce the tunnel. On the other side of the mountain, the Italian Government is engaged in constructing, at the cost of 28,000,000f., a line of railway which will unite Iselle at the southern end of the tunnel with Arona on the Lake Maggiore, the present northern terminus of the Haute Italie railways. The Simplon Railway Company are now, therefore, about to commence the tunnel which, when terminated, will complete the straight line of railway extending from Paris to Brindisi, *via* Pontarlier, Lausanne, the Simplon, and Milan, thus obviating the immense angle described by the Mont Cenis route. It may be remembered that the proposal to subsidize the Simplon route was already submitted to the French Chambers in 1873, when it was indefinitely postponed without discussion. This want of proper consideration must be attributed to several reasons. In the first place, the resignation of M. Thiers and other political events absorbed men's minds in France at that moment; secondly, the Compagnie de la Ligne d'Italie, in whose favor the concession had originally been granted, had just failed in an exceedingly discreditable manner, and had been wound up by order of the Swiss Government. Lastly, at that time, when the prospect of completing the St. Gothard tunnel was apparently hopeless, the Simplon route not only seemed to offer no very special advantages to French commerce, but even appeared in the light of a competitor with the Corniche and Mont Cenis Railways, nor were the Paris-Lyon-Mediterranée Railway Company in favor of the undertaking. Now, however, the aspect of affairs has entirely changed. Since 1874 a new company has been intrusted with the execution of the enterprise, and has given most satisfactory proofs of its activity by the completion of the railway up to the very entrance of the proposed tunnel at Brigue. Colonel Cérésole, formerly President of the Swiss Confédération, is the leading spirit and managing director of this company, and is encouraged in his work by the earnest support of such men as Gambetta, Grévy, Léon Say, &c.

Although the tunnel will be rather longer than that of the Mont Cenis, or of the St. Gothard, it will be constructed and worked under very much more favorable conditions than either of them. The entrances to the St. Gothard and Mont Cenis tunnels are both situated at a considerable altitude—the former being at 1,152 meters, and the latter at 1,560 meters above the level of the sea. Consequently, costly zigzag and corkscrew lines of access have been resorted to, in order to reach the entrance of the tunnels, and owing to the very steep gradients, the power of traction required is something enormous. The Simplon tunnel, on the other hand, enters the mountain at its very base. The railway extending from Lausanne up the lower part of the Rhone Valley, is perfectly straight and without any curves, while the gradient nowhere exceeds 10 millimeters—1 in 100. At its exit on the southern side of the mountain, in the Diviera Valley, the gradient is somewhat stronger—13 in 100. In fact, when the tunnel is completed, the highest point of the line between Paris and Milan will not be in the Simplon, but between Dijon and Lausanne. Owing to the low level of the tunnel, the line will not suffer from the frequent interruptions which the snow causes in winter on the Mont Cenis and St. Gothard routes.

Competent geologists declare that the granite and rock of the Simplon are less hard and compact, and that the infiltrations are less serious than those of the St. Gothard and the Mont Cenis. The Rhone at the Swiss and the Diviera at the Italian extremity of the tunnel will provide the hydraulic power necessary for the boring, while, thanks to the temperate climate of the Valais, the works will not be exposed to the risk of being deprived of their motive power during severe winters, as were those of the Mont Cenis and the St. Gothard.

The tunnel will be 18½ kilometers in length, as compared with the 15 kilometers of the St. Gothard and the 12 kilometers of the Mont Cenis tunnels, and, as it is estimated that a daily advance will be made of 9 to 10 meters in the boring, we may look for its completion in seven or even six years' time. Eighty million francs are to be devoted to the undertaking, under the following items: 74,000,000f. for the tunnel itself, estimated at the rate of 4,000,000f. per kilometer. This estimate appears somewhat high when compared with that of the St. Gothard, which is being pierced at the rate of 2,500,000f. per kilometer. One million francs are required for the completion of the roadway in the tunnel, and 5,000,000f. for the construction of the great international station at Brigue, similar to that at Modane, on the Mont Cenis Railway.

Only a very small portion of this sum—viz., 13,500,000f., consists of stock subscriptions, the balance of 66,500,000f. being granted to the company in the form of the following subsidies:—4,500,000f. from the Swiss Federal Government; 5,000,000f. from the Government of the Canton de Vaud; 1,000,000f. from the Government of the Canton du Valais; 3,000,000f. from the Governments of the Cantons de Berne, Fribourg, and Geneva. A grant of 5,000,000f. from the Swiss Occidental Railway Company, which will derive great advantages from the undertaking; and, lastly, 48,000,000f. the subsidy about to be granted by France.—*London Times.*

ORDNANCE AND NAVAL.

Gunnery Experiments.—Sir W. Palliser writes to the *Times*:—"It may be interesting to some of your readers to know that my rifled 64-pounder gun of 58 cwt. has been disabled by a double charge—namely by 6 lbs. of R. L. G. powder and a 66 lb. shot rammed down on 6 lbs. of similar powder and a similar shot. The powder acted with exceptional violence. Some of those present considered that it had 'detonated.' However this may be, the barrel of the gun, though much bulged, is sound, while the casting or shell of the gun is cracked in several places. The thickness of the gun round the front charge is equal to the diameter of the bore. During a previous trial the same effect was produced upon a similar gun by a charge of 30 lbs. of R. L. G. powder and a shot of 150 lbs. weight. In fact, the same barrel has been used in each of the guns. The disabled gun is now being bandaged up with an iron hoop, and will shortly be fired with papier-mâché wads to try the effect of jamming. I submit that one more instance has now been added to the proofs which have gone before that guns which are lined with coiled wrought-iron barrels do not burst, but only become disabled when subjected to excessive strains; and I feel convinced that the substitution of these barrels in the place of steel tubes would prevent any chance of wrought-iron guns being burst in similar circumstances. Looking to the fact that the action of gunpowder is much affected by various circumstances, and that in order to keep the pressures in large guns within due bounds it is actually necessary to make up the cartridges in a peculiar manner and to employ powders of different natures for different guns, it will be seen how difficult it may be to prevent the occasional occurrence of exceptional pressures in large guns. The question is thus one of great importance, and it will, no doubt, receive the attention it deserves." In a subsequent letter to the same journal, Sir W. Palliser adds:—"I should feel obliged if you would allow me to contradict an announcement which has recently appeared in most of the London papers to the effect that I instituted my experiments to oppose the opinion of the Thunderer Committee. I need hardly, I hope, say that my only object is to seek for the truth. I have now before me carefully prepared diagrams, showing the enlargements of the bore caused in one gun by four, and in the other by eight rounds of double charges. In no case has the rear charge of powder caused the slightest expansion in the bore; whilst the expansions which have been caused by the front charge show that the pressures with pebble powder have been very great, and that the pressure due to the R. L. G. powder has been exceptionally violent. I have, therefore, much pleasure in correcting a former opinion which I had formed upon the results of experiments made with muskets, and in stating that the opinion expressed by Captain Noble, and adopted by the Thunderer Committee, is correct as regards the pressure of a forward charge. I am, however, still of opinion that the bursting of the 38-ton gun has been due to a jam, and not to double-loading, and for the following reason: In every case out of 12 rounds with double charges the point of maximum pressure caused by the front charge of powder lay over that charge, and in the rear of the base of the front projectile; while in the Thunderer's gun the point of *maximum* pressure was situated in front of the place where the base of a front projectile would have been had there been one in the gun. As I have been frequently asked whether I believe that double-loading would burst the the Thunderer's gun, I should like to say that, if the gun were double-loaded, so that the front charge should lie in the position in which it was painted upon the outside of the burst gun, I think it would probably burst; but if the charge be rammed well home, then the front powder-charge will come within the coiled breech-piece, and the gun must be a worse gun than I believe it to be if it bursts. I submit that my experiments entitle me to say that a 38-ton gun made upon my plan would not burst under either of the above conditions.

[Note—Since the above was written, the companion gun of the Thunderer has been burst by loading with a double charge.]

The Secretary of the United States Navy, in his annual report on the condition and operations of the Navy Department for the fiscal year ending June 30, 1879, says:—"The condition of the Navy has greatly improved during the last year. There are now in commission thirty-five vessels, consisting of cruisers, monitors, and torpedo boats. Of the different classes, sixteen can be put in condition for sea service in a few months, and twenty could be made ready in an emergency. With this done, the fighting force of the Navy which might be made available in a very short time would consist of eighty-one vessels of all classes. And if to this number be added the four monitors, Terror, Puritan, Amphitrite, and Monadnock, and eight powerful tugs, which can be fitted for either cruisers or torpedo boats, our whole effective fighting force would consist of ninety-three vessels. The monitors could be completed, with the necessary appropriations, without much delay. Of the vessels now used as receiving ships, seven are unfitted for any other service. There are twenty-seven vessels unfitted for naval purposes of any kind whatever, but which are a positive expense, as it is necessary to keep in employment a force of shipkeepers to preserve them from entire destruction. Some of them might be profitably converted into merchant vessels, and it would be economy to sell the whole."

The St. Gothard Tunnel.—The two sections of the tunnel were successfully joined on the 29th of February. The entire length is about $9\frac{3}{10}$ miles. The contract for this great work was awarded to M. Louis Favre, of Geneva, on the 7th of August, 1872, and the work on the Italian end was begun almost immediately. On the Swiss side the work was begun in November of that year.

The time allowed for the completion of the work was eight years, only seven and a half of which have elapsed. It is confidently expected that the road through the tunnel will be opened for traffic in October.

BOOK NOTICES.

Ice-Making Machines.—Translated from the French of M. Ledoux, Engineer of Mines. New York: D. Van Nostrand. Price, 50 cts.

This little book (No. 46 of Van Nostrand's Science Series, is a reprint from a series of articles first published in *Van Nostrand's Magazine*, and treats the subject from a purely scientific view; it bears on all its pages the stamp of the thoroughly mathematical mind that wrote it, and is characteristic of French scientists, who, as a rule, reason as thoroughly and as strictly mathematically as non-scientific writers are superficial, especially when they treat upon scientific subjects. The art of refrigeration is based on strict physico-mathematical principles, especially since the discoveries of modern science respecting the convertibility of heat into motion, or inversely, the possibility of lowering temperatures by the transmission of heat by means of proper appliances. The author does the subject justice in a mathematical point of view, and continually applies algebraic formulas, with which the book abounds; many of these formulas require a knowledge of the higher branches of mathematics to understand them. For this reason we fear the book will do little good among those in this country who search for information upon the subject. Mathematical knowledge is too rarely diffused, and very few, if any, will be able to profit practically by the truths which can be deduced from the formulas.

The book treats all the different classes of refrigerating machines first those based on compression and expansion of air, and only mentions Giffard's machine; the next class are those in which a volatile liquid is used, and among which are only mentioned sulphuric ether, sulphurous oxide, ammonia, and methylic ether; while the machines using chymogen or petroleum ether, bisulphide of carbon, and liquefied carbonic acid, which have attained some reputation in the United States, chiefly from a scientific point of view, are ignored, simply for the reason that they are not yet known in France; but as the laws are the same, the formulas used for the ethers are also applicable to the first mentioned, while those for ammonia may be applied to carbonic acid, of course with the proper correction of the boiling points, which are much lower in the last mentioned liquids.

Finally, those machines are treated which are based on what is here called "chemical ical action," but what we would only call "solubility." As the type mentioned, Carré's first ammonia machine acts by the strong solubility of ammoniacal gas in water, and in this sense the refrigerating mixtures belong do this class, but these the author only omits.

The ultimate results arrived at are that, theoretically, from 1,200 to 1,500 negative caloric units may be obtained for every kilogram of coal burned, all which, when reduced to Fahrenheit units and pounds, means that for every pound of coal consumed we may subtract a quantity of heat equivalent to 4,000 or 4,500 units; this is about 80 per cent. above the results obtained in practice, so that only about 800 to 900 units of heat can actually be abstracted. The difference between theory and practice must be attributed to external losses of temperature, to imperfect action in the exchanges of heat, but chiefly in the expenditure of work in driving the pumps. If we consider that in the steam engine as much is lost, the ice machines, which are only in their infancy, are better than the steam engine, which has been in operation and improved upon for more than three generations.—*Manufacturer and Builder.*

Report of the Topographical Survey of the Adirondack Wilderness of New York. By Verplanck Colvin. Albany: For sale by D. Van Nostrand.

Most lovers of the forests regard the Adirondack region as exhibiting in the fullest degree the characteristics of unreclaimed wildness. All the charms that belong to a wilderness that is nearly pathless, and that is covered by wild vegetation that is nearly impenetrable, will for a long time yet invest this region and tempt lovers of untrained nature to attractions they can scarcely find so accessible elsewhere.

The enormous wealth of this region in lakes, woods, mountains and wild game was not appreciated until the earlier reports of Mr. Colvin were published.

The last report covered the work of the year 1873. The present one extends from 1874 to 1879.

It is filled with maps and with statistical tables of heights and distances. It will be regarded as indispensable by all the frequenters of this charming region.

Steel: Its History; Manufacture; Properties and Uses, by J. S. Jeans, Secretary of the Iron and Steel Institute. London and New York: E. & F. N. Spon. For sale by D. Van Nostrand. Price, $14.50.

This work bears the appearance of an encyclopedia, and a cursory examination of its index and its pages tends to the theory that it presents as complete an account of steel as can be gathered from the literature of the subject.

The work is divided into four sections indicated by the title.

The historical portion is again subdivided into chapters; each giving the history of steel-making in a distinct geographical region.

The section relating to Manufacture describes fully the many processes, and is illustrated by a good supply of plates and cuts.

The sections relating to Properties and Uses, are not wanting in interest nor completeness.

The author intimates that the work does not claim to be a metallurgical treatise. It is intended to aid the general reader, the statistician and the user of steel as much as the manufacturer; and if its main value should be found to lie in its historical qualities, such a result will only accord with its original design. The subject has been treated throughout with reference to giving it a popular as well as a scientific interest, on the presumption that the general public can hardly be uninterested about the development of one of the most remarkable industries of modern times. It is presumed that the value of the work is not thereby diminished to those who produce or select materials for construction.

The book contains 858 pages, and is illustrated by 23 plates and 186 wood cuts.

The Car-Builders Dictionary. By Mathias N. Forney, M.E. New York: Railroad Gazette. For sale by D. Van Nostrand. Price, $2.00.

This is an illustrated dictionary in the fullest sense of the term, every separable part of a railway car is defined and illustrated by a woodcut. The work was compiled for the Master Car-Builders Association, and was rendered necessary by the differences in the nomenclature employed by car builders in different parts of the country. Thus the Draw-bar is known as Pull-iron, Shackle-bar and Bull-nose respectively, in as many different sections.

The compiler makes conspicuous acknowledgements of the assistance of Mr. Garey of the N. Y. Central & Hudson River Railroad, and of Mr. Calvin A. Smith, of the Master Car-Builders Association.

An Historical Sketch of Henry's Contribution to the Electro-Magnetic Telegraph: With an Account of the Origin and Development of Prof. Morse's Invention. By William B. Taylor. Washington: Government Printing Office.

A new interest attaches to the early progress in Telegraphy in these times of rapid development of electrical science, and while this interest is enlivened is a fitting time to present to the general reader the history of the earlier progress in this direction, and to assert the lawful claims to distinction of those scientists to whom the world is indebted.

Most of this history has only been previously presented in a fragmentary manner in magazine articles, or else in exeeedingly brief form in text books on electricity.

The present sketch is timely and will doubtless be widely read.

MISCELLANEOUS

Temperature of Town Water Supplies. A paper was read on this subject at the recent meeting of the British Association by Mr. Baldwin Latham, in which attention was drawn to the fact that the temperature of the water-supply of a town, as furnished by public waterworks, was totally independent of the temperature of the water at its source of supply, and that invariably the temperature of the water is the temperature of the ground at any season of the year at the depth at which the distributing mains were laid. The average temperatures throughout the year, whatever the source or mode of supply, varied very little, but there was great difference in the range of temperature, and that while temperature in the chalk wells at Croydon gave an average monthly range, based upon daily observations, of 0.64°, the same water when supplied direct from the mains gave an average monthly range of 21.14°, or when stored in a cistern a range of 28.05°; while water supplied from the Thames in Westminster gave an average monthly range of 24.69°, but the average yearly difference of temperature between the chalk water supplied at Croydon and the Thames water supplied in Westminster was only 0.67°

Artesian Wells in Central Australia. Successful borings for water have been made in Frome County, South Australia, in a district hitherto almost devoid of surface water, and regarded as consequently almost worthless for agricultural or pastoral purposes. One well, sunk in some arid country near Lake Frome, at a distance of 400 miles north of Adelaide, as the crow flies, which has been bored to the depth of 370 feet, produces a daily supply of 10,000 gallons of excellent water; and other artesian wells in the same district have proved equally successful. As the result of the enterprise, we are told that, whereas that country would formerly only carry a few thousand head of stock, its capabilities are now practically unlimited. This success will stimulate similar enterprise elsewhere. Much of the so-called desert country forming the boundary between the coast district and the rich pastoral lands which have been discovered in the interior of the continent will be reclaimed by this means. The South Australian Government is sending a scientific expedition to the shores of the Great Australia Bight, with a view to the selection of proper sites for artesian wells to tap the deep springs which are known to exist there; so that a part of the country which has hitherto been regarded as almost the most inhospitable portion of Australia will, by this means, says the *Colonies and India*, be thrown open to agricultural enterprise.

Incombustible Wood.—M. M. P. Folbarri claims that he has discovered a method by which wood of any kind can be rendered incombustible. The following chemical compound is said to produce the result:—Sulphate of zinc, 55 lbs.; American potash, 22 lbs.; American alum, 44 lbs.; oxide of manganese, 22 lbs.; sulphuric acid of 60°, 22 lbs.; water 55 lbs.; all of the solids are to be poured into an iron boiler containing the water at a temperature of 45° C., or 113° F. As soon as the substances are dissolved, the sulphuric acid is to be poured in little by little, until all the substances are completely saturated. For the preparation of the wood, it should be placed in a suitable apparatus, and arranged in various sizes (according to the purposes for which it is intended) on iron gratings, care being taken that there is a space of about half an inch between every two pieces of wood. The chemical compound is then pumped into the apparatus, and as soon as the vacant spaces are filled up it is boiled for three hours. The wood is then taken out and laid on a wooden grating in the open air, to be rendered solid, after which it is fit for uses of all kinds, as ship-building, house-building, railway carriages and trucks, fence-posts, wood-paving—in short for any kind of work where there is any liability to destruction by fire.—*Building News*.

Breaking Ice with Dynamite.—Some experiments of this order were recently made on the Seine, near the Pont des Invalides, in presence of a large crowd massed on the quays. Two civil engineers, MM. Bernard and Lay, directed operations, and they were aided by MM. Flegy and Streits, of the Noble Dynamite Company. The experiments were six in number. In the first, a cartridge of 80 grammes on a float placed in a hole of 20 centimeters diameter, was exploded with a Bickford fuse; it enlarged the hole 75 centimetres, and cracked the ice to a length of 6 metres. The second cartridge of 250 grammes, placed similarly under the ice with a Bickford fuse, projected vertically to a great height a mass of water and *debris*, and dislodged nearly 100 cubic metres of ice. The third experiment, which was the most important, was made with three cartridges of 406 grammes, each connected by conducting wires with an electric machine on the bank. The portion of ice shattered was about 80 meters long by 5 to 6 metres broad. This experiment seems to have indicated the right way to follow, for not only was a large quantity of ice separated from the mass, but it was in very small pieces; this would obviate agglomeration against the arches of bridges. The three remaining experiments were made with cartridges of 400 grammes, exploded with the Bickford fuse. The dislocations were about 15 to 20 metres in extent, which can be doubled by introducing levers into the fissures produced by the explosion.

Gold in Russia.—The St. Petersburg papers report a great development of the gold production of Russia. Strata containing gold in considerable quantity have recently been discovered in the Ural Mountains. It is said that in the district of Sennigsei, a Russian proprietor has found in his gold mine, near Motygynn, a nugget 445 lbs. in weight, representing a value of nearly £15,000.

The deepening of the Seine between Rouen and Paris, which will materially encourage the importation of English coals into Paris, is exciting a good deal of dissatisfaction among the coal-owners of Pas-de-Calais and Nord. Among several schemes for improved water-way from the north to Paris, the one which appears to find most favor is that which commences at Haute Deule, near Noyelle-Godault, passes near Arleux, Peronne, Ham, Noyon, and Méry-ser-Oise, reaching Paris at the Villette basin. This route is not only the shortest between the coal fields in Paris, but it will also give greatly increased facilities for obtaining cheaper coals at Amiens and Beauvais. The coal owners are desirous that the canal and locks should be of sufficient width to accommodate vessels of 500 tons. The estimated cost is 74 1-2 million francs.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXVII.—MAY, 1880.—VOL. XXII.

THEORY OF THE STRENGTH OF LONG COLUMNS.

By WARD BALDWIN, University of Cincinnati.

Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

ALTHOUGH several new formulæ for determining the strength of columns have been recently proposed, and some comparison made between the numerical results obtained by experiment and from the different formulæ, there seems to have been no attempt to show that the formulæ now in general use are incorrect. The significance of the constants in Gordon's formulæ seems, indeed, to be not generally understood. It is the purpose of this paper to derive and discuss Gordon's and Hodgkinson's formulæ.

SHORT PRISMS.

As the resistance of materials to crushing has always been intimately associated with the theory of the strength of columns the method of obtaining the crushing strength will be briefly noticed. Malleable metals, such as wrought iron, when subjected to compression yield by buckling or by flowing laterally, and cannot strictly be said to have a crushing strength. However, the ultimate resistance of wrought iron to compression has been variously estimated at from 36000 to 90000 lbs. per square inch by different authors. This disagreement between the values assigned to the crushing strength must be attributed to the diversity of opinion as to what the crushing strength of such metals may be defined to be. When the material is of granular texture, prisms of not less than one and a half nor more than three diameters long, subjected to a compressive stress yield without flexure, fracture taking place along nearly plane surfaces. The values of the moduli of rupture thus obtained are evidently applicable to determine the strength of beams and columns made of granular materials, as these when fractured on the compressed side yield by a wedge being forced out at the point of rupture.

When a short prism is uniformly loaded the pressure is uniformly distributed over any ideal plane section. Therefore, if p represents the intensity of a uniform load applied to a prism bounded by horizontal and vertical faces, the intensity of vertical stress on any horizontal plane section is p; and on a section inclined at an angle ϑ to the horizon is $p.\cos\vartheta$. The intensities of the tangential and normal components of stress on this plane are respectively

$$p.\cos\vartheta.\sin\vartheta = p_t, \text{ and } p.\cos^2\vartheta = p_n.$$

Let f represent the coefficient of friction —assumed to be constant—of the material at the point of abrasion; then the intensity of frictional resistance to the separation of the prism at any plane section is $f.p_n = f.p.\cos^2\vartheta$. The intensity of stress tending to produce fracture along any plane is therefore

$$p_\vartheta = p(\cos\vartheta.\sin\vartheta - f.\cos^2\vartheta) \; . \; . \; . \; (1)$$

Fracture will evidently take place along the plane which has such an inclination that p_ϑ has its maximum value on that plane. To find the inclination of the plane for which p_ϑ is a maximum equate

$\frac{dp_\vartheta}{d\vartheta}$ to zero, and then solve for ϑ.

$$\frac{dp_\vartheta}{d\vartheta}=p[\cos^2\vartheta-\sin^2\vartheta+2f.\sin\vartheta.\cos\vartheta]=0$$

$$\therefore\ \cos^2\vartheta-\sin^2\vartheta+2f.\sin\vartheta.\cos\vartheta=0$$

and $$\vartheta_m=\tan^{-1}(f+\sqrt{1+f^2})\ .\ .\ .\ (2)$$

The positive sign is given to the radical in (2) because ϑ_m must be greater than 45°. For when 0 is substituted for f in (2) the value of ϑ_m is 45°; and since f is always greater than zero, ϑ_m must be greater than 45°, for p_n will then be less than p_t as it evidently must be when p_ϑ has its maximum value. As there are an infinite number of plane sections of equal areas inclined at the angle ϑ_m, it is obvious that when a prism of homogeneous material yields to compression two cones, whose vertices lie at the same point in the axis of the prism, will be formed. If the material is not homogeneous the prism will be fractured along the plane where the resistance is least. It is evident, therefore, that the resistance of prisms of the same material to compression is proportional to the area of the cross-section. If 0.4, which is the value of the coefficient of friction for cast iron at the point of abrasion determined by Rennie, be substituted in eq. (2) for f, then $\vartheta_m=\tan^{-1} 1.477 = 55°54'$. This value corresponds with the empirical value of ϑ_m found by Hodgkinson, who states in his work on cast iron that ϑ_m is somewhat less than 56°.

If the deviation of the plane of fracture from the inclination of 45° for which p_t is a maximum is wholly due to the action of a force analagous to friction, as has been assumed above, it follows that p_ϑ is of such magnitude that the frictional resistance and the resistance to shearing along the surface of fracture are together equal to p_ϑ. If, then, $f.p.\cos^2\vartheta$, which is the intensity of frictional resistance, be subtracted from p_ϑ, the modulus of shearing will be obtained. Let S denote the modulus of shearing, then

$$S=p[\cos\vartheta.\sin\vartheta-2f.\cos^2\vartheta].$$

Substitute for p the value of the modulus of rupture for cast iron of the brand "Low Moor No. 3," which is 109801 lbs., and make f=0.4 and ϑ=55°54'; then S=.213×109801=23387 lbs. Rankine gives 27000 lbs. as the average value of S for cast iron. This relation between the crushing and shearing strengths of materials can be verified by experiment alone.

When prisms too short to be fractured by shearing are compressed the length of the prism is decreased, the right section is augmented, and the prism is fractured when the strain produced by lateral enlargement overcomes the cohesion of the particles of the material. In this change of form the friction between the ends of the prism and the surfaces, between which the prism is crushed prevents, to some extent, lateral spreading of the material there, and thus adds an important element of strength to the prism. Although the friction increases with increase of intensity of pressure, and is therefore greater the stronger the material, yet it is not known that the influence of the friction on the apparent strength of such prisms is proportional to the strength of the material. So that moduli of resistance obtained from experiments on such prisms are greater than the intrinsic strength, and are not known to represent the relative strength to resist crushing except under the peculiar conditions of the experiments.

LONG COLUMNS.

The strength of prisms of such length that when subjected to compression they deflect appreciably from a straight line is determined by the formulæ for the strength of long columns. The power of long columns to resist fracture, other things being equal, depends on the method of supporting the ends; and it is usual on this basis to classify long columns under three general heads, according as they are free to turn about both ends; are fixed at both ends; or are fixed at one end and free to turn about the other end.

COLUMNS FREE TO TURN ABOUT BOTH ENDS.

Let the neutral axis of a column free to turn about both ends be referred to rectangular co-ordinates, the origen being at one end, and the axes of X and Y vertical and horizontal respectively. Let the load supported by the column be denoted by P. Then, since the moment of internal resistance at any section must be equal to the moment of the external forces,

$$P.y=\frac{EI}{R}=EI\frac{-\frac{d^2y}{dx^2}}{\left\{1+\left(\frac{dy}{dx}\right)^2\right\}^{\frac{3}{2}}}$$

the negative sign being used because the curve is concave to the axis of X. As the curvature of the column is practically very slight, the inclination of the column to X and therefore $\frac{dy}{dx}$ also will be very small at any point; so that $\left(\frac{dy}{dx}\right)^2$ may without material error be neglected in the expression for P.y. The equation of moments may then be written

$$\frac{d^2y}{dx^2}+P.y.\frac{1}{EI}=0.$$

This is a "linear" equation the complete integral of which is

$$y=(c_1+c_2)\cos\left\{x\sqrt{\frac{P}{EI}}\right\}$$
$$+\sqrt{-1}\,(c_1-c_2)\sin\left\{x\sqrt{\frac{P}{EI}}\right\},$$

c_1 and c_2 being constants of integration. Since $y=0$ when $x=0$, therefore $c_1=-c_2$ and

$$y=2c_1\sqrt{-1}\sin\left\{x\sqrt{\frac{P}{EI}}\right\}$$
$$=h\sin\left\{x\sqrt{\frac{P}{EI}}\right\} \quad . \quad . \quad . \quad (3)$$

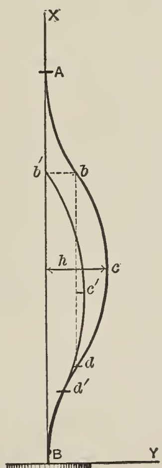
where $2c_1\sqrt{-1}=h$ for convenience. If the curvature of the column be so slight that the abscissa of the end of the column differs inappreciably from the length of the column, equation (3) gives for this point

$$0=h\sin\left\{l\sqrt{\frac{P}{EI}}\right\}$$

where l is the length of the column. Since $\sqrt{\frac{P}{EI}}$ cannot be zero it follows that $l.\left\{\sqrt{\frac{P}{EI}}\right\}=n.\pi$; n being some whole number. Now $\left\{x.\sqrt{\frac{P}{EI}}\right\}=0$ when $x=0$; so that as x changes from 0 to l, $x.\sqrt{\frac{P}{EI}}$ changes from 0 to $n.\pi$, and must therefore pass through the value $\frac{\pi}{2}$. When $x.\sqrt{\frac{P}{EI}}=\frac{\pi}{2}$, y has its maximum value h, which corresponds to the abscissa $x=\frac{l}{2}$. If n be greater than unity there will evidently be n values of x that make $\sin\left\{x\sqrt{\frac{P}{EI}}\right\}=1$, and there will therefore be n points at which $y=h$; but as there can be only one such point n must be unity. The value of P found from equation (3) when n is unity is

$$P=\frac{\pi^2 EI}{l^2} \quad . \quad . \quad . \quad (4)$$

This is the equation proposed by Euler for determining the strength of uniform



elastic columns which are free to turn about the ends, and erroneously supposed to express the resistance to "incipient flexure."

COLUMNS FIXED AT BOTH ENDS.

If the column is not free to turn about the ends but is fixed vertically there, the line AcB in the figure represents on an exaggerated scale the curvature of the neutral axis of such a column. Fixing a column at the ends is equivalent to introducing a couple at each end of such magnitude as to keep the tangents there always vertical. Let M represent the moment of the end couple. The equation of moments for any section is then

$$P.y-M=\frac{EI}{R}=-EI.\frac{d^2y}{dx^2},$$

if the flexure is so small that $\left(\frac{dy}{dx}\right)^2$ may be neglected in the value of R. The value of y found by equating $\frac{d^2y}{dx^2}$ to zero is $y=\frac{M}{P}$, which is the value of y at the points of inflexion b and d. Substitute z for $\frac{dy}{dx}$ in the equation of moments, multiply by $z.dx=dy$, and integrate; then

$$\tfrac{1}{2}z^2=\frac{M}{EI}.y-\tfrac{1}{2}\frac{P}{EI}.y^2+c,$$

or, replacing z by $\frac{dy}{dx}$,

$$\left(\frac{dy}{dx}\right)^2=\frac{2M}{EI}.y-\frac{P}{EI}.y^2+c.$$

Since $\frac{dy}{dx}=0$ when $y=0$, the constant of integration c is zero

$$\therefore\left(\frac{dy}{dx}\right)^2=\frac{-P}{EI}.y^2+\frac{2M}{EI}.y \quad . \quad . \quad . \quad (5)$$

The maximum value of y, found by equating $\frac{dy}{dx}$ to zero, is $y=\frac{2M}{P}$. Equation (5) solved for dx and then integrated gives

$$x=\sqrt{\frac{EI}{P}}\left\{\cos^{-1}\left(\frac{P.y}{M}-1\right)\right\}+c.$$

The value of c, found by making x and y zero, is

$$c=-\sqrt{\frac{EI}{P}}(2n-1)\pi.$$

$$\therefore x=\sqrt{\frac{EI}{P}}\left\{\cos^{-1}\left(\frac{P.y}{M}-1\right)-(2n-1)\pi\right\}.$$

This equation solved for y gives

$$y=\frac{M}{P}\left\{1+\cos\left(x\sqrt{\frac{P}{EI}}+(2n-1)\pi\right)\right\}$$

$$=2\frac{M}{P}.\sin^2\left\{\frac{x}{2}\sqrt{\frac{P}{EI}}\right\} \quad . \quad . \quad . \quad (6)$$

In this equation substitute for y its maximum value $\frac{2M}{P}$, and for x substitute $\frac{l}{2}$, which is the abscissa of the middle point c when l differs inappreciably from the abscissa of the end of the column; then

$$\frac{2M}{P}=\frac{2M}{P}\sin^2\left\{\frac{l}{4}\sqrt{\frac{P}{EI}}\right\} \quad \therefore \frac{l}{4}=\frac{\pi}{2}\sqrt{\frac{EI}{P}}.$$

Now in equation (6) substitute $\frac{M}{P}$, the value of y at the points of inflexion, for y; then

$$\sin\left\{\frac{x}{2}\sqrt{\frac{P}{EI}}\right\}=\frac{1}{\sqrt{2}} \text{ and } x=\frac{\pi}{2}\sqrt{\frac{EI}{P}}$$

$$\text{or } \frac{3\pi}{2}\sqrt{\frac{EI}{P}}=\frac{l}{4} \text{ or } \frac{3l}{4}.$$

Thus the points of inflexion divide the column into segments such that $Ab=bc=cd=dB$ in the figure. Since $y=0$ when $x=l$, equation (6) becomes, when l is substituted for x,

$$\sin\left\{\frac{l}{2}\sqrt{\frac{P}{EI}}\right\}=0. \therefore \frac{l}{2}\sqrt{\frac{P}{EI}}=n\pi$$

where n must be unity for the same reasons as in the case of columns free to turn about the ends. The value of P found from this equation is

$$P=\frac{\pi^2 EI}{\left(\frac{l}{2}\right)^2}=\frac{4\pi^2 EI}{l^2} \quad . \quad . \quad . \quad (7)$$

From this equation it appears that as regards resistance to flexure a column fixed at the ends has the same strength as one half as long and free to turn about the ends.

COLUMNS FIXED AT ONE END.

It is evident from the figure that the stress in each of the segments Ab, bc, cd, dB of a column fixed at both ends is the same as the stress in either half of a column free to turn about both ends, and twice as long as one of the segments. The portion bcd of the column will therefore represent a column of the same strength which is free to turn about the ends b and d. The value of P for a column free to turn about the ends given in eq. (4) is expressed in terms of l, the length of the column; so that if l_1 denote half the length of the column, $P=\frac{\pi^2 EI}{(2l_1)^2}$. This equation is true then for each of the four equal segments of a column fixed at the ends, when l_1 is the length of each segment. Since at the point of inflexion b there is no flexure, the stress in the rest of the column will not be altered if the part above b is removed and the load is applied directly at b. The value of P for each of the segments bc, cd, dB of length l_1, and, therefore, for the whole columns is

$$P=\frac{\pi^2 EI}{(2l_1)^2}=\frac{\pi^2 EI}{\left(\frac{2l}{3}\right)^2}=\frac{9\pi^2 EI}{4l^2} \quad . \; . \; . \; (8)$$

where l is the length of the column bB. Suppose the end b to be now moved to the point b' on the vertical tangent to the neutral axis at B. The flexure in the segment bcd will thereby be increased, while the flexure in the segment db will be diminished; and the neutral axis will assume the position $b'c'd'$B, and will then represent the curvature of the neutral axis of a column fixed at one end and free to turn about the other end. Although equation (8) is thus seen to be not strictly true for such a column, yet as bb' is very small this equation is considered to be sufficiently near the truth for practical purposes.

The expressions for P deduced by considering the stress induced by flexure alone are constant for a given column, provided the deflection is small, and hence follows the conclusion of Euler that P is the power of columns to resist "incipient flexure." But the strength of the material is reduced by an amount equal to the compressive stress produced by the direct action of P, so that, if P is to express the ultimate strength of the column, the values of P found above must be reduced by this amount. Let c denote the modulus of rupture for compression of the material, and let $\frac{P}{S}=Q$ be the intensity of compressive stress due to the direct action of P, where S=area of cross-section. Then $\frac{Q}{c}$ is the part of c that is overcome by the direct action of P, and therefore $\left(1-\frac{Q}{c}\right)$ is the part of c that is free to resist stress induced by flexure. So that, since the transverse strength is proportional to the modulus of rupture, the true value of the ultimate strength of columns is found by multiplying the values of P in equations (5), (7) and (8) by $\left(1-\frac{Q}{c}\right)$. Substitute Q.S for P in these equations so altered, and solve for Q; then for columns

Free to turn about both ends

$$Q=\frac{c}{1+\frac{c}{\pi^2 E}\cdot\frac{Sl^2}{I}}=\frac{c}{1+\frac{c}{\pi^2 E}\left(\frac{l}{\rho}\right)^2}\ldots(9)$$

Fixed at both ends

$$Q=\frac{c}{1+\frac{c}{4\pi^2 E}\cdot\frac{Sl^2}{I}}=\frac{c}{1+\frac{c}{4\pi^2 E}\left(\frac{l}{\rho}\right)^2}\ldots(10) \quad (A)$$

Fixed at one end

$$Q=\frac{c}{1+\frac{4c}{9\pi^2 E}\cdot\frac{Sl^2}{I}}=\frac{c}{1+\frac{4c}{9\pi^2 E}\left(\frac{l}{\rho}\right)^2}\ldots(11)$$

In these equations I is the least moment of inertia, and ρ is the least radius of gyration of the transverse section of the column. These formulæ which are seen to have the same general form as Rankine's formulæ were proposed by John D. Crehore in the December number of this Magazine for 1879; and differ from Rankine's formulæ in the more definite form of the second term of the denominator.

Equation (9), (10) and (11) are founded on the hypothesis that the material is fractured by a compressive stress. Since the compression due to flexure acts with and augments the stress due to the direct action of the load, it follows that the material on the concave side of the curve assumed by a loaded column is more severely strained than on the convex side, where the tension produced by flexure is wholly or partly neutralized by the compression due to the load. But when the tensile strength of a material is much less than the compressive strength, a column made of such material may yield on the convex side to the tensile stress induced by flexure. When such is the case, if t denote the modulus of rupture for tension and Q as before the unit stress due to the direct action of the load, then $\frac{Q}{t}$ is the part of t by which the strength of the column to resist tension is increased. So that the true value of the ultimate strength of columns is found by multiplying the values of P in equations (5), (7) and (8) by $\left(1+\frac{Q}{t}\right)$. Substitute $Q.s$ for P in the equations so altered, and solve for Q; then for columns

Free to turn about both ends

$$Q=\frac{t}{\frac{t}{\pi^2 E}\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (12)$$

Fixed at both ends

$$Q=\frac{t}{\frac{t}{4\pi^2 E}\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (13) \quad \text{(B)}$$

Fixed at one end

$$Q=\frac{t}{\frac{4t}{9\pi^2 E}\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (14)$$

Where ρ as before denotes the least radius of gyration of the transverse section of the column. It is thus seen that it is possible to have two formulæ for determining the value of Q for any particular column. The correct value of Q is evidently determined by the formulæ that gives the less result, and according as this formula is one of set (A) or of set (B) the column yields to compression or tension.

Cast iron, if we except stone, is the only material ordinarily used for columns that fulfills this condition; the average ratio of the crushing strength of cast iron to the tensile strength being about six. The moduli of rupture of cast iron of the brand "Low Moor No. 3" for compression and tension are 109,801 lbs. and 14,535 lbs. respectively. And in the experiments of Hodgkinson on solid cylindrical columns of this brand of cast iron, all columns with rounded ends when more than ten diameters long, and all with flat ends when more than about eighteen diameters long, were torn asunder on the convex side by the tensile strain due to flexure. This may be easily verified from Hodgkinson's experiments by dividing the breaking weights by the area of cross section of the columns to find Q, and then adding this value of Q to the modulus of rupture for tension and substracting it from the modulus of rupture for compression to get the unit stress due to flexure necessary to break the column. The process that gives the less result evidently determines whether the column yields to tension or compression. So that if t and c denote the moduli of rupture for tension and compression, then if $(t+Q)<(c-Q)$, the column yields to tension; and if $(t+Q)>(c-Q)$ the column yields to compression. When $(t+Q)=(c-Q)$ the column will yield equally to tension and compression.

TABLE I.

Columns with Flat Ends.			Columns with Round Ends.		
$\frac{l}{d}$	$(t+Q)$	$(C-Q)$	$\frac{l}{d}$	$(t+Q)$	$(C-Q)$
9.7	82045	42291	9.8	63815	60521
13.1	70495	53841	13.2	53135	71201
15.1	65785	56551	15.2	40195	84141
19.5	60135	64201	19.9	32625	91711
19.7	53305	71031	23.4	27725	96611
24	51178	73158			

If the moduli of rupture of the cast iron used by Hodgkinson in his experiments be substituted for t and c in the above equation, then $[14535+Q]=[109801-Q]$, and this gives $Q=47633$ lbs.; so that $[t+Q]=[C-Q]=62168$. In the accompanying table the values of $[t+Q]$ and $[C-Q]$ calculated from Hodgkinson's experiments, are seen to approach the value 62168 as $\frac{l}{d}$ approaches 18 when the ends are flat, and 10 when the ends are round. The yielding of long cast iron columns to tension accounts for the greater strength of long wrought iron columns.

GORDON'S FORMULAE.

For Cast Iron.—The fundamental hypothesis on which the above discussion depends is, that E, the modulus of elasticity, is constant. As is well known, however, this is not the case when the material is strained to near the ultimate strength, and hence it might be inferred that the general formulæ deduced on this hypothesis cannot be used to determine the ultimate strength of columns. The coefficient of $\left(\frac{l}{\rho}\right)^2$ in formulæ (A) and (B) is the product of some constant into $\frac{C}{\pi^2 E}$ or $\frac{t}{\pi^2 E}$; so that if E is constant the whole coefficent of $\left(\frac{l}{\rho}\right)^2$ is constant, and (A) and (B) may be replaced by the general formulæ

$$Q=\frac{c}{1+a\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (15)$$

and

$$Q=\frac{t}{a\left(\frac{l}{\rho}\right)^2-1} \quad . \quad . \quad . \quad (16)$$

where to a must be assigned the values of the coefficients of $\left(\frac{l}{\rho}\right)^2$ in (A) and (B). When the column is a solid cylinder the value of ρ in terms of the diameter d of the transverse section is $\rho^2=\frac{d^2}{16}$; and when this value is substituted for ρ^2 in equations (15) and (16) the general equations for solid cylindrical columns are

$$Q=\frac{c}{1+16a\left(\frac{l}{d}\right)^2} \text{ and } Q=\frac{t}{16a\left(\frac{l}{d}\right)^2-1}.$$

Let a_r denote the value of $16a$ for columns free to turn about the ends, and a_f for columns fixed at both ends. The values of a_r and a_f computed from the experiments of Hodgkinson on solid cylindrical cast iron columns are given in table II. Equations (15) or (16) was used in these computations according as the columns yielded to compression or tension, and to c and t were given the values $c=109801$ lbs., and $t=14535$ lbs. The device adopted by Hodgkinson to allow the columns free motion about the ends was to make the ends rounded; and to fix the ends he made them flat. It appears from equations (A) and (B) that the coefficient of $\left(\frac{l}{d}\right)^2$ should have the same value for columns fixed at both ends that it has for a column half as long and free to turn about both ends; and in order that the comparative values of a_r and a_f may be more readily apparent $2l$ is substituted for l for columns fixed at both ends. So that instead of the values of a_f corresponding to different values of $\frac{l}{d}$, we have the values of $4a_f$ which correspond to different values of $\frac{l}{2d}$. The lengths of the columns are given in inches. The value of a instead of being constant is seen to increase quite uniformly as $\frac{l}{d}$ decreases, the greatest value of a_r when $\frac{l}{d}=9.8$ being nearly ten times the value for $\frac{l}{d}=121$; and the value of $4a_f$ for $\frac{l}{2d}=6.6$, being more than ten times the value for $\frac{l}{2d}=60.5$.

Since when c and t are made equal to the moduli of rupture the coefficient of $\left(\frac{l}{\rho}\right)^2$ is not constant, if it is possible for this coefficient to be constant when to c in equation (15) is assigned some value other than the modulus of rupture, let f denote this value of c. The general equation then is

$$Q=\frac{f}{1+a\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (17)$$

which for solid cylindrical columns, when ρ is expressed in terms of the diameter d, becomes

$$Q=\frac{f}{1+16a\left(\frac{l}{d}\right)^2}.$$

If different values be assigned to a, and the corresponding values of f be computed from the values of Q found by experiment, it is found that when a_f is less than about $\frac{1}{400}$, f increases as $\frac{l}{d}$ decreases, and when a_f is greater than

TABLE II.—CAST IRON.

Round Ends.					Flat Ends.				Discs on Ends.	
l	$\frac{l}{d}$	a_r	f when $a_r=\frac{1}{100}$	f when $a_r=\frac{1}{200}$	$\frac{l}{2d}$	$4a_f$	f when $a_f=\frac{1}{400}$	f when $a_f=\frac{1}{200}$	$\frac{l}{d}$	f when $16a=\frac{1}{800}$
	121	.001432	104900	54020	60.5	.001939	89630	176900	121	46010
	78.6	.001567	105100	53410	39.2	.002438	86530	167800	78	49600
	61.1	.001844	94710	48580	30.6	.002953	85530	162800	60.5	48610
60.5	46.9	.001968	100400	52400	23.5	.003970	72840	147400	47.2	48380
	39.8	.002164	100800	53380	19.4	.005204	72170	129200	39.5	49400
	34.2	.002808	80740	43560						
	31.2	.002965	84410	46240						
	60.5	.001720	103120	52960	30.2	.002969	85910	163350	30.2	61350
	39.2	.002266	95823	50840	19.6	.004600	91630	164300		
30.25	30.5	.003148	81690	43790	15.0	.006992	82390	139400		
	23.4	.003839	85430	49340					Mean, 50560	
	19.9	.004556	89720	53900						
20.1	19.9	.004851	77402	46500	20.2	.004364	94920	171100		
	26.2	.002517	112300		12.9	.008564	88180	143200		
					9.8	.014172	76370	114000		
	30.2	.002731	98110	53910	15.1	.006288				
15.1	19.9	.004331	100800	60580	9.8	.013948	88920	132200		
	15.2	.006780	84920	55290	7.6	.019968	80460	109600		
12.1					12.1	.009540	90330	144000		
					7.7	.020020	79920	109600		
10.0	13.2	.007847			10.1	.012928	91880	138250		
					6.6	.022424	80030	104100		
7.56	15.2	.006649	89780	58180	7.6	.016012	90000	122700		
	9.8	.012790	96590		4.8	.016820	83370	99240		
Mean values........			94039	51617			84790	138902		

about $\frac{1}{400}$, f decreases as $\frac{l}{d}$ decreases. It follows, therefore, that f must be constant for some value of a_f a little greater or less than $\frac{1}{400}$. The mean value of f when $a_f=\frac{1}{400}$ is 84790, and none of the values of f differ from the mean value more than 15 per cent. The variations in the values of f seem due to empirical anomalies, and are independent of change in the value of $\frac{l}{d}$. If 80000 be taken as the value of f, the value of Q for solid cylindrical columns with flat ends is,

$$Q=\frac{80000}{1+\frac{1}{400}\left(\frac{l}{d}\right)^2};$$

and the general equation for columns with flat ends, found by substituting for d its value in terms of ρ, is

$$Q=\frac{80000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (18)$$

In "Trautwine's Engineer's Pocket Book" the coefficient of $\left(\frac{l}{\rho}\right)^2$ is given as $\frac{1}{3200}$ instead of $\frac{1}{6400}$. This value makes $a_f=\frac{1}{200}$, and it is seen from the table that the corresponding value of f decreases as $\frac{l}{d}$ decreases, so that a_f must be less than $\frac{1}{200}$. Also the mean value of f is nearly 139000 instead of 80000.

If simply making the ends of a column flat were sufficient to keep the column fixed in direction at the ends, then it follows from equations (9) and (10) that equation (18) will determine Q correctly for a column free to turn about the ends when $2l$ is substituted for l. When this substitution is made, $a_r=4a_f=\frac{1}{100}$; and the corresponding values of f in the table are seen to decrease as $\frac{l}{d}$ decreases, the mean value of f being 94000. Since f decreases as $\frac{l}{d}$ decreases a_r must be less than $\frac{1}{100}$. When $a_r=\frac{1}{200}$ the mean value of f is 51617, and the variations in the value of f seem to be independent of changes in the value of $\frac{l}{d}$. If 50000 be taken as the value of f the value of Q for solid cylindrical columns with round ends is

$$Q=\frac{50000}{1+\frac{1}{200}\left(\frac{l}{d}\right)^2};$$

and the general equation for columns with round ends, found by substituting for d its value in terms of ρ, is

$$Q=\frac{50000}{1+\frac{1}{3200}\left(\frac{l}{\rho}\right)^2}. \quad . \quad . \quad (19)$$

Hodgkinson found by experiment that cylindrical columns with flat discs on the ends are stronger than columns that have simply flat ends. As this additional strength can only be due to the fact that the discs hold the ends more firmly fixed than the flat ends of the column itself, it follows that a column with flat ends is not rigidly fixed in position there, but holds some place intermediate between a column free to turn about the ends and one fixed at the ends; so that the formula for columns free to turn about the ends cannot be derived directly from the formula for columns with flat ends, as has been found above. When, however, $\frac{l}{2}$ is substituted for l in eq. (19) the resulting equation should give the values of Q for columns with discs on the ends, provided the discs are sufficiently large to hold the ends rigidly in position. The general equation for columns fixed at the ends is then

$$Q=\frac{50000}{1+\frac{1}{12800}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad (20)$$

which gives for cylindrical columns, when $\frac{d^2}{16}$ is substituted for ρ^2,

$$Q=\frac{50000}{1+\frac{1}{800}\left(\frac{l}{d}\right)^2}.$$

The values of f, computed from Hodgkinson's experiments, on solid cylindrical columns with discs on the ends, given in the table, are somewhat less than the values of f for columns free to turn about the ends; the mean value, omitting the last, being 48600. This discrepancy can only be accounted for by supposing the discs not large enough to secure the ends rigidly. If in equation (19) $\frac{2l}{3}$ be substituted for l the resulting equation will, according to eq. (11), be the formula for determining the strength of columns fixed at one end and free to turn about the other end; so that

$$Q=\frac{50000}{1+\frac{1}{7200}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (21)$$

is the general equation for columns fixed at one end. For solid cylindrical columns this becomes, on substituting for ρ^2 its value in terms of the diameter,

$$Q=\frac{50000}{1+\frac{1}{450}\left(\frac{l}{d}\right)^2}.$$

In the only experiment on a cylindrical column with a disc on one end, recorded by Hodgkinson, the length of the column was 30.25 inches, the diameter was one inch, and the empirical value of Q was 17272 lbs.; while equation (21) gives Q=16815 lbs. Hodgkinson gives three experiments on columns flat at one end and free to turn about the other end; but in the absence of more data equation (21), which gives results somewhat less than these experiments, seems the best that can be derived for columns flat at one end. The general formulæ for cast iron collected together for convenient reference are then, for columns—

Free to turn about both ends

$$Q=\frac{50000}{1+\frac{1}{3200}\left(\frac{l}{\rho}\right)^2}$$

Fixed at both ends

$$Q=\frac{50000}{1+\frac{1}{12800}\left(\frac{l}{\rho}\right)^2}$$

Fixed at one end

$$Q=\frac{50000}{1+\frac{1}{7200}\left(\frac{l}{\rho}\right)^2}$$

Flat at both ends

$$Q=\frac{80000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2}$$

WROUGHT IRON.

Since the tensile strength of wrought iron is fully as great as its compressive strength, wrought iron columns always yield to a compressive strain, so that the general formula for wrought iron is

$$Q=\frac{c}{1+a\left(\frac{l}{\rho}\right)^2}$$

where to a must be assigned the values of the coefficient of $\left(\frac{l}{\rho}\right)^2$ in equations (A). But since the value of c has never been accurately determined, and as the same objection to the use of formulæ in which E is considered to be constant holds as well for wrought iron as for cast iron, the general formula may be written

$$Q=\frac{f}{1+a\left(\frac{l}{\rho}\right)^2}$$

where a and f are to be found empirically. The values of f in table III are computed from the experiments of Hodgkinson on solid rectangular and cylindrical columns. When the column is rectangular, if h denote the less side of the rectangle, $\rho^2=\frac{h^2}{12}$; and when the column is cylindrical, if d denote the diameter of the cylinder, $\rho^2=\frac{d^2}{16}$. So that the general formula for rectangular columns is

$$Q=\frac{f}{1+12a\left(\frac{l}{h}\right)^2}$$

and for cylindrical,

$$Q=\frac{f}{1+16a\left(\frac{l}{d}\right)^2}.$$

From the values of f in the table for columns with flat ends it is seen that f increases as $\frac{l}{h}$ increases, when $12a=\frac{1}{1000}$, and therefore $12a$ must be less than $\frac{1}{1000}$. When $12a=\frac{1}{3000}$ the mean value of f, omitting the first, is 36699 for rectangular columns, and the mean value for cylindrical columns is 36985. The value assigned to f for $12a=\frac{1}{3000}$, by Gordon, is 36000; and if this value is retained the formula for rectangular columns is

$$Q=\frac{36000}{1+\frac{1}{3000}\left(\frac{l}{h}\right)^2}$$

and for cylindrical columns

$$Q=\frac{36000}{1+\frac{1}{2250}\left(\frac{l}{d}\right)^2}$$

The general formula for wrought iron columns with flat ends, derived from the preceding formulæ by substituting for d and h their values in terms of ρ, is

$$Q=\frac{36000}{1+\frac{1}{36000}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (22)$$

The values of f when $12a=\frac{1}{2500}$ and $16a=\frac{1}{1875}$ seem to be more uniform than when $12a=\frac{1}{3000}$ and $16a=\frac{1}{2250}$, but the difference is not great except for the first column where the value of $\frac{l}{h}$ is 7.3.

It has been shown that a cast iron column is not rigidly fixed in direction at the ends when the ends are flat, and the few experiments made by Hodgkinson on wrought iron columns with rounded ends indicate that this is also true for wrought iron columns. If a column with flat ends were rigidly fixed, then according to eq. (9) the value of Q for columns with rounded ends would be given by eq. (22) when $2l$ is substituted for l; so that

$$Q=\frac{36000}{1+\frac{1}{9000}\left(\frac{l}{\rho}\right)^2}$$

would be the formula for columns with rounded ends. This gives for solid cylindrical columns of diameter d

$$Q=\frac{36000}{1+\frac{1}{562}\left(\frac{l}{d}\right)^2}$$

The values of f in the table corresponding to $16a=\frac{1}{562}$ increase as $\frac{l}{d}$ decreases, and therefore $16a$ must be greater than $\frac{1}{562}$. When $16a=\frac{1}{400}$ the variations in

Table III. Wrought Iron.

Rectangular Columns. Flat Ends.

$\frac{l}{h}$	f when $12a=\frac{1}{1000}$	f when $13a=\frac{1}{2500}$	f when $12a=\frac{1}{3000}$
7.3	53650	45350	49550
14.6	43860	37500	37010
29.3	49290	34050	32600
30	56340	40330	38550
39	70010	44660	41860
58.6	80300	40980	37020
59	89570	47820	43190
60	77480	41100	37060
60	83110	44080	39740
60	81370	43160	38920
78	91910	44550	39290
80	75220	36190	31850
88	85280	39950	34930
90	90090	41970	36630
90	84440	39350	34340
118	83630	36810	31620
119	86380	37955	32570
	Mean	40936	36699

Cylindrical Columns. Flat Ends.

$\frac{l}{d}$	f when $16a=\frac{1}{1875}$	f when $16a=\frac{1}{2250}$
15.4	38480	37760
29.8	42560	40280
59.3	45710	40740
88.9	38610	29160
	41340	36985

Cylindrical Columns. Round Ends.

$\frac{l}{d}$	f when $16a=\frac{1}{562}$	f when $16a=\frac{1}{400}$
15.4	42480	47250
19.8	43710	50980
58.1	41780	55850
59.6	28300	48080
89.2	33740	46500
	Mean	49732

the value of f are independent of the values of $\frac{l}{d}$, so that, if 49000 be taken as the value of f, the formula for solid cylindrical columns with rounded ends is

$$Q=\frac{49000}{1+\frac{1}{400}\left(\frac{l}{d}\right)^2}$$

The general formula for columns free to turn about the ends, found by substituting $16\rho^2$ for d^2, is

$$Q=\frac{49000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (23)$$

The formula for columns fixed at the ends is derived from eq. (23) by substituting $\frac{l}{2}$ for l in that equation; so that for columns fixed at the ends

$$Q=\frac{49000}{1+\frac{1}{25600}\left(\frac{l}{\rho}\right)^2} \quad . \quad . \quad . \quad (24)$$

The only experiment on a column with discs on the ends recorded by Hodgkinson was made on a solid cylindrical column 30.25 inches long and 1.015 inches in diameter. The breaking weight was 25387 lbs., and equation (24) gives Q.S=25490 lbs., where S is the area of the cross-section. The formula for columns fixed at one end and free to turn about the other end may be derived from eq. (23) by substituting $\frac{2l}{3}$ for l; so that for columns fixed at one end

$$Q=\frac{49000}{1+\frac{1}{14400}\left(\frac{l}{\rho}\right)^2}$$

The general formulæ for wrought iron are then, for columns:—

Free to turn about both ends

$$Q=\frac{49000}{1+\frac{1}{6400}\left(\frac{l}{\rho}\right)^2}.$$

Fixed at both ends

$$Q=\frac{49000}{1+\frac{1}{25600}\left(\frac{l}{\rho}\right)^2}.$$

Fixed at one end

$$Q=\frac{49000}{1+\frac{1}{14400}\left(\frac{l}{\rho}\right)^2}.$$

Flat at both ends

$$Q=\frac{36000}{1+\frac{1}{36000}\left(\frac{l}{\rho}\right)^2}.$$

WOODEN COLUMNS.

Experiments on wooden columns have been limited in number, and the available experimental data on the strength of pine columns seem insufficient to determine a satisfactory formula. A few experiments by Lemandé on square oak columns with flat ends, which are quoted by Hodgkinson in the *Phil. Trans.*, 1840, and the experiments made by Hodgkinson on square columns of Dantzic oak with flat ends are here used to derive formulae for the strength of oak columns. The crushing strength of the oak used in Lemandé's experiments was 6336 lbs. per square inch. When this value is given to f in the general equation

$$Q=\frac{f}{1+a\left(\frac{l}{\rho}\right)^2}=\frac{f}{1+12a\left(\frac{l}{h}\right)^2},$$

where h is the side of the square, the corresponding values of $12a$ in the table are seen to decrease as $\frac{l}{h}$ increases, $12a$ being more than twice as great for $\frac{l}{h}=6$ as for $\frac{l}{h}=36$. When $12a=\frac{1}{400}$, since f increases as $\frac{l}{h}$ increases, $12a$ is two large; and when $12a=\frac{1}{700}$, since f decreases as $\frac{l}{h}$ increases, $12a$ is too small. So that $12a$ has some value between $\frac{1}{400}$ and $\frac{1}{700}$ for which value f is constant. Owing to the small number of experiments and to the anomalies in some of the results the value of $12a$ can be only approximately determined; and $\frac{1}{550}$ seems to be near the truth. The mean value of f corresponding to $12a=\frac{1}{550}$ is, in round numbers, 5600; and the formula for square oak columns with flat ends is

$$Q=\frac{5600}{1+\frac{1}{550}\left(\frac{l}{h}\right)^2} \quad . \quad . \quad . \quad (25)$$

The general formula for oak columns with flat ends is, therefore,

$$Q=\frac{5600}{1+\frac{1}{6600}\left(\frac{l}{\rho}\right)^2}$$

where ρ is the radius of gyration of the transverse section. The crushing strength of the Dantzic oak used by Hodgkinson in his experiments was 7731 lbs. per square inch. When $12a=$

TABLE IV.

Lemande's Experiments.									Dantzic Oak.		
l	h	$\frac{l}{h}$	$12a$ when $f=6336$.	Values of Q. S. By experim't.	Values of Q. S. By eq. (25)	f when $12a=\frac{1}{400}$	f when $12a=\frac{1}{550}$	f when $12a=\frac{1}{700}$	$\frac{l}{h}$	f when $12a=\frac{1}{600}$	f when $12a=\frac{1}{1000}$
25.5	4.25	6.0	.00530	96001	94980	5793	5660	5586	16.9	6321	5501
25.5	3.18	8.02	.00400	50958	50698	5851	5629	5498	17.3	6999	6065
25.5	2.13	12.0	.00330	19495	20050	5864	5443	5197	27.4	5888	5280
51.0	3.18	16.03	.00300	36223	38547	5885	5258	4896	30.7	9013	6808
76.5	4.25	18.0	.00270	60783	63660	6091	5347	4923	34.6	9403	6898
76.5	3.18	24.0	.00196	29961	27590	7247	6079	5401	45.2	7575	5233
51.0	2.13	23.99	.00224	12523	12370	6753	5667	5047			
76.5	2.13	35.98	.00210	7769	7547	7282	5765	4897		Mean	5964
					Mean value,		5606				

$\frac{1}{600}$, since f increases as $\frac{l}{h}$ increases, $12a$ is too large. When $12a=\frac{1}{1000}$ the mean value of f is nearly 5900, and the variations in the value of f seem to be independent of $\frac{l}{h}$; so that the formula for square columns of Dantzic oak with flat ends is

$$Q=\frac{5900}{1+\frac{1}{1000}\left(\frac{l}{h}\right)^2}.$$

The general formula for columns of Dantzic oak is, therefore,

$$Q=\frac{5900}{1+\frac{1}{12000}\left(\frac{l}{\rho}\right)^2}.$$

ρ being the least radius of gyration of the transverse section.

Hodgkinson's experiments have been used to deduce the formulæ for iron because they are the most accurate and extensive that have yet been made; and also in offering an interpretation of the values given to f by Gordon it seemed best to use the same data that Gordon did.

The experiments on wrought-iron columns of the full size used in practice, and embracing all ordinary forms, which were made under the supervision of G. Bouscaren, Consulting and Principal Engineer of the Cincinnati Southern Railway, and which are contained in the report published by Thos. D. Lovett in 1875, while of great practical value are not suitable to form the basis of general formulae. The columns were placed horizontally, and pressure applied with a hydraulic press. Mr. Bouscaren is authority for the statements,—that no allowance was made for friction between the parts of the press; that in some of the experiments made in winter glycerine, instead of water, was used in the press; and that the experiments were mostly made in close proximity to heavy machinery, which kept the columns in constant vibration. The experiments have accomplished their object in establishing the correctness of Gordon's formulae when applied to built columns. Also from the results of these experiments Mr. Bouscaren has been led to incorporate in his specifications for bridges, the rule that the thickness of the metal in a column shall not be less than one-thirtieth of the horizontal distance, nor than one-sixteenth of the vertical distance between consecutive rivets. It was found when columns were proportioned according to this rule that the plates buckled at the same time that the column bent, and that hence the maximum efficiency of the material was secured.

HODGKINSON'S FORMULAE.

Although Hodgkinson has proposed formulae for wrought-iron and wooden columns, similar to his formulae for cast-iron columns, the latter alone have ever been much used. The general form of Euler's formulæ, given in equations (4) and (7), is $P=C\frac{I}{l^2}$; C being a constant depending on the method of fixing the ends, and I the moment of inertia of the transverse section of the column. For cylindrical columns of diameter d this equation becomes $P=\frac{\pi C}{64}\cdot\frac{d^4}{l^2}$. Hodgkinson, accepting the formulae proposed by Euler as theoretically correct, assumed the value of the breaking weight for solid cylindrical columns to be given by the equation $P=C\frac{d^m}{l^n}$, where C, m, and n are constants to be determined by experiment. In the *Phil. Trans.*, 1840, Hodgkinson has discussed his formulae for cast-iron columns so exhaustively that nothing further is needed to clearly understand them. The assumption made by him that the strength of hollow cylindrical columns is equal to the difference between the strength of solid columns having diameters equal to the external and internal diameters of the hollow column should be noticed. The general form of Gordon's formula,

$$P=Q.S=\frac{f\cdot S}{1+a'\left(\frac{l}{\rho}\right)^2}$$

has been shown to give results agreeing with experiments on both iron and wood, when f and a' have proper values, and the experiments on built columns made by Bouscaren show that this formula is *generally* true. Let d_1 be the internal and d_2 the external diameters of a hollow column; and S_1 and S_2 the areas of the corresponding circles; then if the assumption made by Hodgkinson be true,

$$\frac{f(S_2-S_1)}{1+a\frac{l^2}{d_1^2+d_2^2}}=\frac{f.S_2}{1+a\frac{l^2}{d_2^2}}-\frac{f.S_1}{1+a\frac{l^2}{d_1^2}}$$

$$\therefore \frac{(S_2-S_1)(d_2^2+d_1^2)}{d_1^2+d_2^2+al^2}=\frac{S_2d_2^2}{d_2^2+al^2}-\frac{S_1d_1^2}{d_1^2+al^2}$$

substitute for S_1 and S_2 their values in terms of the diameters, then

$$\frac{d_2^4-d_1^4}{d_1^2+d_2^2+al^2}=\frac{d_2^4}{d_2^2+al^2}-\frac{d_1^4}{d_1^2+al^2}.$$

Since the right hand member of this equation is greater than the left, it follows that a hollow column is not as strong as the difference between the strengths of two solid columns. If the above equation be reduced to a common denominator it reduces to $0=al^2.d_1^2d_2^2(d_2+d_1)(d_2-d_1)\ \therefore\ d_2=d_1$, which is impossible. Hodgkinson's formulae for cylindrical cast-iron columns are

$P=14.9\frac{d^{3.6}}{l^{1.7}}$ tons, for solid columns with rounded ends.

$P=44.16\frac{d^{3.6}}{l^{1.7}}$ tons, for solid columns with flat ends.

$P=13\frac{d_2^{3.6}-d_1^{3.6}}{l^{1.7}}$ tons, for hollow columns with rounded ends.

$P=44.3\frac{d_2^6-d_1^6}{l^{1.7}}$ tons, for hollow columns with flat ends.

The coefficient for columns with round ends is a little less for hollow than for solid columns, as it should be; but for columns for flat ends the coefficient is greater for hollow than for solid columns. These coefficients are the mean values computed from many experiments, and the coefficient for hollow columns with flat ends is the mean not only of the values of the coefficient for columns with flat ends, but also for columns with discs on the ends, which accounts for its greater value.

The conclusion that the strength of a hollow cylindrical column is less than the difference between the strengths of two solid columns having diameters equal to the internal and external diameters of the hollow column may be reached independently of Gordon's formula. According to the general theory of flexure, a longitudinal shearing stress is induced when a girder is bent. In illustration of this, Rankine adduces the familiar fact that a pile of boards of equal lengths will slide upon one another when bent, and the ends will not then lie in a plane. It follows immediately from this principle that the strength of a hollow column will be less than the difference between the strengths of two solid columns by an amount at least equal to the shearing stress which would be produced over the inner surface if the column were solid.

SUBURBAN HOUSE DRAINAGE AND WATER SUPPLY.

By ROBERT VAWSER, C. E.

From "The Archictect."

I PROPOSE to describe very briefly the drainage and water supply at a large detached mansion in Cheshire, the residence of about forty or fifty persons. An outbreak of fever was the immediate cause for undertaking the works, and for the same reason the remedy was as thorough and complete as possible, and nothing that prudence could suggest to prevent a recurrence of the outbreak was neglected.

An inspection of the premises revealed many serious defects.

Some of the drains were brick circular drains; some had inverts and covers of stone with brick sides; they were generally 3 feet in diameter, or 3′0″×2′6″ square, and had been altered and extended from time to time, and were irregular in direction, size, and depth: they were nearly filled with accumulations of sewage sediment, and in many places were under the buildings. The waste pipes and several grids in the larder, kitchen, and cellar were untrapped; the floors were honey-combed with rats, and there was practically no obstacle to the uncontrolled escape of sewer gas into the living apartments.

Most of the water closets were new and in good working order; their soil pipes were ventilated at the top by 2-inch pipes, but they communicated direct with the sewer, as also did the waste pipes from the wash bowl, urinal and housemaids' closets; these latter had lead syphon traps under the basins.

In designing the new drains, very great care was taken to prevent the escape of sewer gas into the house, and wherever a drain approached the house its continuity was broken by a water trap and ventilator. All the old drains were taken up, the mud removed from under the house, and the space made good with clean earth or concrete; the rat-runs and useless drains were destroyed.

The clean water draining from the cellars, together with the overflow from cisterns and tanks, has been taken off by a special drain; the sewage is collected separately into 9-inch stoneware pipes, and purified on a small plot of land carefully underdrained and planted with comfrey, a very prolific plant, well suited for sewage cultivation, and as food for cattle.

Near the center of the main buildings three water closets, a wash bowl, a urinal, and three sink waste pipes discharge at the same place; these have been conducted into an "Edinburgh trap," the object of which is to stop the direct flow of sewer gas, by a water trap, and to admit fresh air at the base of the soil and waste pipes; the ventilation of these pipes is further ensured by continuing them at their full size to the roof. The drains have been ventilated by some of the rain water spouts, and by special ventilators in open places. The waste pipes from kitchen, laundry, &c., have been taken through the outside wall, and discharge on the top of trapped gullies; many useless grids both inside and outside the premises have been dispensed with.

The water supply was found to be very inferior; it consisted of surface water collected on cultivated land, and was otherwise polluted; it was consequently abandoned, and a better supply sought elsewhere.

The mansion is situated over the red marl in which the salt deposits of Cheshire are found; the surface is covered with a great thickness of drift sand and gravel. It occupies an elevated position, and is surrounded by a considerable area of table land, which upon examination was found to contain an abundant supply of pure water fit for every domestic purpose; a cutting having been made in the slope leading from the table land, a flow of nine *gallons* per minute was quickly yielded, and it was ascertained this could be increased to almost any reasonable extent.

The level of the cutting yielding this water is so much above the valley contiguous to it, that it was found practicable to raise all the water required for the use of the mansion by hydraulic power: this is effected by one of Douglas's hydraulic rams, placed in the valley about 15 feet below the spring; the ram is 80 feet below the tank on the roof of the mansion; it has required no attention or repairs, and has supplied a continuous flow of water, at the rate of 1,000 gallons per day, for the last six months.

The roof water from a very large area of slates and lead is likewise collected, affording an ample supply for every purpose.

It was at first expected steam or horse power would have been required to pump from some distant source, and the discovery of a copious supply so near at hand was made almost by chance, the application of this discovery may possibly sometimes prove the solution of one great difficulty in rural districts, viz: the water supply to small communities. Parliament fixes the value of a supply of water to a cottage at 2*d.* per week, which will shortly be increased to 3*d.* per week. It is difficult to work within this limit, but an apparatus, such as described, would supply a group of cottages or a mansion at a very trifling expense.

Its great merit is that no permanent expense is incurred, the apparatus really requires no attention, and will work continuously if let alone.

The Local Government Board urgently exhorts local authorities to improve their supplies of water, but the prices legally chargeable to consumers are seldom remunerative if costly engineering undertakings are forced upon small communities. The water resources of the country have lately been prominently discussed, and the opinion appears to prevail, that relief must be sought in the development of local resources, rather than in colossal national undertakings.

One reason for presenting this paper is to direct special attention to the question of house drainage, a subject often neglected by the engineer, who not unfrequently devotes his entire attention to the main and outfall works, and neglects minute details. It should never be forgotten that however important and interesting the outfall and main drainage may be, they form but a small portion of the ultimate cost; and the health of the community, which is the sole object of all sewerage undertakings, is influenced less by them than by details that are often overlooked.

People living in cottages are generally less exposed to infection from sanitary defects than those in houses of the better class, where every water closet, bath, and entrapped cellar drain, is a source of constant danger. The best and only security against danger from these is a continuous current of fresh air through the soil and waste pipes; a 1-inch or 2-inch ventilator at the top of the soil pipe is practically useless; every soil pipe should be quite open at the top, and have an equal inlet for fresh air near the bottom, and should be kept outside the house if possible.

The cellar drain when connected with a common sewer should have a water trap and ventilator just outside the building, in addition to the gully within, and the slopstone waste pipe should not be laid direct to the sewer, but to the top of a trapped gully outside the building.

It is most important that the execution or workmanship of all drains or other sanitary appliances should be of the best possible; on no account ought works of this nature to be left to the discretion of the least unintelligent workman, as is too often the case: care is necessary to ensure uniform and sufficient gradients; this is quite as important in small as in large works, and should be jealously watched; every pipe should be ranged or boned in, and laid at a gradient proportioned to the size of the pipe and the flow of sewage along it. As a general rule, house drains are too large; a 9-inch pipe is sufficient for almost the largest mansion, or a village say of 1,000 inhabitants, provided the gradients are good and surface water excluded from the drains.

An endeavor has been made to fulfill these conditions in the works forming the principal subject of this paper. The details can hardly be described at greater length without the aid of diagrams.

If we consider the condition in which the mansion was found, and in which other residences are known to be, it becomes a matter for reflection whether the system of inspection by local authorities is carried far enough. In new buildings disgraceful blunders are sometimes perpetrated through ignorance or neglect; and we have an accumulation of such blunders as a legacy from an age when sanitary measures obtained but little attention. The condition of the new offices of the Local Government Board at Whitehall may be taken as an instance of the former, and Marlborough House of the latter class.

New Mountain Guns.—A complete battery of six guns on a novel principle have just been completed at the Royal Gun Factories, Woolwich, and will be issued for service. They are called "mountain guns," but instead of weighing merely 200 lbs., like the "mountain gun" used in Abyssinia and Zululand, they will weigh 400 lbs. each. As, however, an essential condition of mountain artillery is that every part of it shall be carried on the backs of mules, these guns are made in two pieces, screwed together, and strengthened at the joint by a third piece in the shape of a ring or collar. The breech end of the gun when disjointed weighs 200 lbs., and the barrel with collar amounts to about the same weight, which is regarded as a fair burden for a mule over hilly country. These guns, like their smaller namesakes, are of the small calibre adopted for 7-pounder projectiles, but their greater length and weight enable them to do much more effective work. They have been made from a design by Sir William Armstrong.

THE ACOUSTIC PROPERTIES OF BUILDINGS.

From "The Architect."

"The Construction of Buildings in Relation to Sound" formed the subject of an interesting paper, which was read at the meeting of the Musical Association.

Mr. Cecil C. Saunders, the author, said that with the growing appreciation of and the desire to hear good music, has come in a great measure the modern importance of the subject. The construction of buildings of the class for enabling large numbers of persons, at once, to hear vocal and instrumental music to the best advantage might be considered under six primary heads or divisions, viz., size, shape, proportion, situation of the singer or orchestra, materials employed, and the bearing of all these upon the kind of music to be performed. It was difficult to find a building equally well adapted for the hearing by a large number of both slow music and rapid. It would be obvious that the size of a concert-room depended more upon the amount of disposable funds than anything else, and equally obvious that a small room would not be so liable to acoustical defects as a large one. It should be remembered that every listener must have from five to six square feet in area; and as music should be good, and good music should be heard in comfort, six square feet was not at all too much to give to each seat, including passages between one part and another. This would give an area of 6,000 square feet for 1,000 auditors, or 30,000 square feet for 5,000, which, he thought, was almost the greatest number that could reasonably be expected to hear good music well. The shape of a concert-hall was too frequently subservient to that of the plot of ground on which it was to be placed; and here it was that the architect had to make use of all his ingenuity, and the utmost fertility of his resources, in order to obtain the largest amount of accommodation upon the site at his disposal. The usual shape of a concert-hall was a rather long rectangle; if for a large audience, galleries were introduced at the end, and perhaps at the sides, the orchestra being placed opposite the end gallery. This form had its advantages, but for a large hall it had serious drawbacks. If it be very long, a large number of the audience were at so great a distance from the performers that the waves of sound, being interrupted, did not reach the more distant listeners with anything like their initial crispness and force. If, on the other hand, the room was very broad, there was a tendency to echo, as the sound which traveled direct to the listener from the orchestra came to him also from the side walls by a more circuitous route, giving, if not an obvious echo, an indefiniteness and want of decision throughout. This of course would not be the same in all parts of the hall. The height of the room had also to be considered, bearing as it did directly upon its acoustical properties, and the height could only be satisfactorily considered in reference to the contour of the ceiling. A circular room had great disadvantages, particularly when associated with a high and vaulted ceiling. One of the most successful places for hearing that he knew of, which approached to a circular shape, was Surrey Chapel, which had sixteen equal sides and a gallery all round, and was built to accommodate 1,400 persons. It had windows round it, both above and below the gallery; the roof over the center portion was hemispherical, with a small lantern at the apex. This chapel was almost free from echo, but it required a powerful voice to fill it.

Mr. Saunders stated that great height in a concert-room appeared to be disadvantageous to the hearers, and suggested that, having due regard to proper and perfect ventilation, it should not be higher than was necessary. Writing upon concert-rooms, Mr. Statham said "as a general rule, music cannot be really enjoyed in rooms above a certain limit of size, certainly not music requiring delicacy of execution and expression. It may be doubted whether it is possible to enable more than 2,000 persons at the outside to hear an orchestral symphony with full enjoyment and realization of the intended effect." With all due respect to Mr. Statham, he (Mr. Saunders) felt very much inclined to combat his suggestion, and to say that he had little doubt but that 5,000 might, in a properly-constructed building, hear an orchestral symphony with full enjoyment and appreciation of the most delicate points. In considering the size of concert-rooms, the first question that arose was, How far the sound designed to be heard would travel? By far the greater portion of sound, so to speak, went upwards into the air, and but a small part was directed towards the hearing level. A resonant wall or sound reflector, placed anywhere within the limits of the voice, would have the effect of reinforcing the sound between it and the speaker or beyond him to some extent. As to the extraordinary modifying influence upon the intensity of sound which was produced by light, this, he confessed, he was unable to account for or to explain, but thought that when the dynamic force of light was better understood, they would be able to obtain a scientific reason for this remarkable fact. The height at which a ceiling should be placed depended upon the necessity for ventilation and other matters, but, as far as acoustics were concerned, a ceiling should be as low as practicable if the aim be to carry sound far in a horizontal direction. Every foot of additional height lessened the horizontal distance to which the sound could be carried, and consequently the number of possible hearers. The position of the performers on the orchestra ought to engage their attention, as, although little regard was bestowed upon it usually, a great deal of the possible successfulness of a concert-hall was attributable to it.

Mr. Saunders then entered into a detailed statement of what he called "a model concert-hall," which, he stated, should be a square room with rounded corners. In defiance of preconceived notions of symmetry, he proposed to put the orchestra in one corner; it should be capable of seating 700 performers, and of course the orchestra seats must rise tier above tier up into the angle of the building. He would have an organ, and put the greater part of it beneath the orchestra, and have it only visible above so as to permit the ceiling to be as low as possible in order that the voices of the tenors and basses might be diffused perfectly over the whole building. Light for the orchestra and chorus should be obtained from a sun-burner or electric light in the extreme angle of the ceiling, so shaded as to be of the utmost service to the performers, but unseen by the audience. The light would be thrown from behind the chorus and orchestra so as to give them the best possible advantage from it. Ventilation should also be gained by the same means, and by peforation in the ceiling, ribs, and cornice. By placing the orchestra in the angle of the building, the difficulties that arose from its position were obviated, either at the end of a long hall or in the center of the side of a wide one. The auditorium to seat 5,000 persons might have a circular arrangement so as to give everyone a direct view, and therefore a better hearing of the performers. The circles should be described from a point near the center of the orchestra, and the levels of seats should be so arranged as that those sitting in the rear should have no difficulty in seeing and hearing over the heads of those in front, the seats in the extreme angle opposite to the organ being almost as high as the top of the orchestra. Under this arrangement, the sound traveling along, or rather being deflected at a very obtuse angle by the ceiling, would reach those at the greatest distance as clearly as it would those nearer to the performers. As to the materials, great care was necessary in their choice. He would recommend wood for the ceiling, the boards being carefully and accurately tongued and glued together, so that each bay would be one large sounding-board. Plastering, in the ordinary sense, was the worst possible ceiling, and was a non-conductor of sound. Zinc would be nearly as cheap as wood, and perhaps more efficacious. The ceiling might be divided by circular and radial beams, perforated for ventilation. As to the walls and their covering, he believed looking-glasses to be good for this purpose, as they reflected sound, but they should not be bedded in flannel, as was usual; they should be placed on the walls adjoining the orchestra. With regard to the remainder of the walls, he would recommend boarding or cement.

Stone would be better, but its great cost was almost prohibitive. If there was the probability of a sparse audience, heavy curtains should be suspended, wherever necessary, from hooks in the ceiling prepared for the purpose.

A NEW METALLIC COMPOUND.

By GRANVILLE COLE, Ph.D.

From "Engineering."

The paper which I am about to read this evening affords me the privilege of appearing, for the first time, before a meeting of the members of the Society of Arts, and I hope you will grant me your indulgence for any shortcomings which may attend this, my first appearance as a public lecturer in England.

The subject of the paper is the discovery of a metallic compound, which I shall prove to you is new, and I shall endeavor further to set forth a few facts, attested by experiments, in respect of its nature. I am duly impressed with the very technical character of my subject, and the tendency there must be, in dealing with it, towards a certain dryness in my remarks. But, while I trust that many of the data will appeal with special interest to engineers and other practical men, I still hope to arrest your attention by showing you to how many artistic and industrial purposes this new metallic compound may be put. In the first place it will be right to give a brief account of the metal.

Nearly a year ago, Mr. J. Berger Spence discovered that the sulphides of metals, combined with molten sulphur, formed a liquid. This liquid, on cooling, became a solid homogeneous mass, possessing great tenacity, and having a peculiar dark grey—almost a black—color. Nearly every metallic sulphide which is known combines, as experiments have proved, with an excess of sulphur, and curiously enough, nearly all these combinations have the same properties. The combination, of which I have specimens here for inspection, consists of an ore of iron pyrites containing both lead and zinc sulphides.

Examining the metal from a chemical point of view, I may state, briefly, that it is a chemical compound belonging to that class known as thiates, or sulphur sulphides.

Dr. Hodgkinson, chemical demonstrator at the Science Schools, South Kensington, has kindly sent me the following facts. I cannot do better than to quote his letter on the subject:

"It appears to be the easiest thing in the world to obtain a homogeneous casting with it. Specific gravities of portions sent gave 3.3743 to 3.7036 (reduced to 0° C).

"When finely powdered, it is acted upon slowly by concentrated HCl. and NO^2 HO in the cold; in large lumps, little or no action takes place. As yet I have not been able to determine the expansion equivalent accurately; it would appear, however, to be small. The fracture is not conchoidal, as might perhaps have been expected, but somewhat like that of cast iron.

"I have not had time to try many 'utilization experiments' on the substance, but I have no doubt it would be exceedingly useful in the laboratory, even, for instance, for making the air-tight connections between glass tubes by means of caoutchouc, and a water or mercury jacket, where rigidity is no disadvantage; the fusing point is so convenient, about 340°, that it may be run into the outer tube on to the caoutchouc, which it grips, on cooling, like a vise, and makes perfectly tight.

"I don't know what you may call the material, but should think, as it seems to be more than a mere mixture, 'ferric thiate' would not be a bad or inappropriate name."

I propose, this evening, to illustrate, by experiments, such as are possible at a lecture, some of the properties of the metal. I will begin by giving you a short summary of its peculiarities, and its advantages over those of other metals or metallic compounds.

1. It has a comparatively low melting point, viz., 320° Fahr., or rather more than 100° above the temperature of boiling water. Here, then, we have in its favor the small amount of fuel needful to supply the necessary heat for reducing the metal to a condition for use.

2. It expands on cooling, a property not shared by the majority of other metals or metallic compounds. I believe that type metal and bismuth are two exceptions. Later on, I think I shall convince you that, for an operation like the joining of gas and water pipes, this expanding property is one of great importance.

3. It claims to resist atmospheric or climatic influences, as compared with bronze and marble. I noticed only a few days ago how the statues in bronze, on the Holborn Viaduct, had been affected by our London fogs. And I have evidence to produce in the direction of showing the imperviousness of the metal to such degrading influences.

4. As compared with other metals of metallic compounds its resistance to acids, used commercially, to alkalies, and to water, is certainly superior.

5. A smooth surface of this metal or metallic compound, now known commercially as Spence's metal, takes a very high polish. I will illustrate this to you by casting some of this molten metal on to a surface of glass.

It may, perhaps, be interesting to my hearers to learn the manner in which Mr. Spence first thought of utilizing this metal for works of art. In order to obtain a perfectly smooth surface, he had been running molten metal on to a piece of glass as I have just done. But before doing so, he had chanced to touch the glass, and had left the marks of the pores of the skin of his fingers upon it. On removing the metal, these marks were found to be reproduced, and so indelibly that they did not disappear on polishing the surface metal. This led Mr. Spence to try to cast the metal in a mould; and although at present no artistic work of high order has yet been reproduced, yet I venture to think that enough has been done to justify the expectation that, in a short time, standard works of both ancient and modern art may be successfully and usefully reproduced. Various colors, such as the green patina of bronze, the dark blue hue of steel, and the appearance of silver and gold, have already been obtained. Experiments are now in progress, which give promise of enabling those who adopt this metallic compound for such uses, to reproduce metallic works in their original colors.

I have here a casting that was made from a nickel-plate engraving; every line, however minute, has been reproduced in Spence's metal. Experiments are now being carried on to test the adaptability of the metal for printing and stereotyping purposes, but they are not complete, so I refrain from giving you any facts about them.

Besides this, experimental castings have been made of various medallions and busts; notably, this large bust of her Majesty the Queen. The metal in this case has not subsequently been treated in any way beyond being polished with a cloth. The metal can be cast into almost any material used for moulds.

Mr. Spence has succeeded in obtaining casts from metal moulds, plaster moulds, and even from gelatine moulds. These last are probably the first metallic castings produced from gelatine moulds. Spence's metal being almost a non-conductor of heat, cools so rapidly in the gelatine mould that it yields a perfect impression before the form of the mould is destroyed, and if the gelatine be allowed to remain on the metal till cold, it remodels itself ready for the next casting. It is, therefore, hoped that an additional process has been secured, by which the most undercut objects may be reproduced successfully and easily.

The advantages which Spence's metal possesses over other materials used for artistic productions may be summarized under three heads, viz: 1. Cheapness. 2. Facility of working. 3. Resistance to climatic influences.

CHEAPNESS.

As compared with lead, which is one of the cheapest of metals, it is one-third the weight; and, whereas the average cost of lead for the last ten years has been nearly £18 a ton, Spence's metal only costs £15. A ton of Spence's metal being three times the amount in bulk of that of a ton of lead, it is available for three times the amount of work. It may, therefore, be considered to be nearly a quarter of the price of lead, and, consequently, very considerably less than that of bronze.

FACILITY OF WORKING.

Its melting point being very low, it can be very easily prepared for pouring into a mould, and its property of expanding, when cooling, causes it to take such a perfect impression, that the cast requires very little chasing after. In respect of a gelatine mould, which can cover a considerable surface of work without joints, such as one has to make in plaster piece moulding, the metal cast obtained from such a mould would require no chasing whatever.

RESISTANCE TO THE ATMOSPHERE.

With regard to its resistance to climatic influences, experiments have been conducted in this direction with complete success. A polished surface of the metal has been exposed for six months in all weathers, without showing the least change.

Mr. Wood, the secretary of this Society, has had a medallion, which I sent him a month ago, exposed to all the recent fogs and frosts, on the outside of this building. You can judge and see for yourselves how well it has stood this test.

Not to confine myself to his test alone, I have here another medallion of this metal, which Mr. Wood tells me has been left for the same period in aqua-regia, one of the strongest acids known. You see how little effect the acid has had on the surface of the metal. I believe that no work of art in any other substance would bear this test without suffering. I will here endeavor to show you the effect the same acid has on marble or bronze. I venture to think that if Spence's metal has resisted this acid for a month, it ought certainly to be able to resist the climate of London for a very much longer period. I, therefore, beg to submit that this metal, if skilled labor is brought to bear on it, ought to be of great value for decorative purposes, both internal and external.

I will endeavor now to point out to you the uses to which this metal may be applied for industrial purposes. And I propose to divide these purposes under three heads: 1. Gas and water works. 2. Chemical works. 3. Miscellaneous.

GAS AND WATER WORKS.

As practice is better than theory, I will simply relate, as best I can, those experiments which have been tried at the South Metropolitan Gas Works. Experiments, under the direction of Mr. Livesey, were made some weeks back; two pipes were joined by this metal in much less time than would have been taken had lead been employed. The pipes, after having been joined, were tested under pressure but no leakage was found.

METHOD OF JOINING PIPES WITH LEAD.

In order to show the especial advantages this metal has over lead, it will be as well here, if I endeavor to tell you how gas or water pipes are joined when lead is used. The pipes having been laid together, the joint is packed with yarn; clay is then laid round the exterior of the joint, and the molten lead is run in. Unfortunately, lead possesses the property of contracting on cooling. The leaden joint has, therefore, to be "caulked," or, as it is called in the north, staved. This caulking, or staving, means wedging the lead into the joint, in order to obtain a perfectly tight joint. This caulking naturally occupies considerable time, and necessitates excavation, in order to allow the men to work all round the pipes.

Excavation and caulking are both rendered unnecessary by the use of Spence's metal. The pipes have only to be laid together, and after the yarn has been forced into the joint and the clay placed, the liquid metal is run into the joint, the clay is removed, and the joint is finished. The metal does not splash in running into the mould, thus avoiding a great source of waste of material, and danger to workmen.

Experiments were also tried to test the metal joints in the event of subsidence of the ground. Four lengths of 9 ft. piping, 6 inch diameter, were joined with the metal, and supported on trestles.

After the metal had set, which it did in a few minutes, the center supports were knocked away, leaving only the two end ones. The 36-ft. length of piping sank 7 inches, without showing, even after pressure, a leakage.

These experiments were so satisfactory, that the South Metropolitan Company have adopted the metal, and are now laying their pipes with it. Mr. Livesey, the chief engineer, in writing on the subject to Mr. Spence, says: "We have now only the test of time, and that, I think, we may take the risk of." Others of the London gas works, and a very large number of provincial gas works, are adopting it.

In the same way, it will be useful for water works. Mr. Hope, who undertook some experiments in Scotland, reports that at the Edinburgh Water Works two pipes were joined and subjected to a pressure of 400 ft. of water, which was as much as they could get on without the joint showing any leakage. This is the greatest pressure which we have as yet been able to put it to; so what it will actually bear, I am not at present in a position to say.

From a sanitary point of view, as water has no action on the metal, it would be extremely valuable for cisterns, instead of iron or lead. Being almost a non-conductor of cold, pipes might be lined with it to prevent the water from freezing.

USES TO CHEMICAL WORKS.

The metal being less acted upon by acids than other metals, it may also be of service to chemical manufacturers. I refer especially to sulphuric acid, which is the most extensively used of all acids in commerce. Lead has, up to the present, been used for sulphuric acid tanks. I have myself tested the metal with sulphuric acid, and its action is almost imperceptible. The one objection to the use of this metal in this case is its low fusing point, but when acids have only to be used up to a certain temperature, say 200° Fahr., I venture to predict a large field for its use.

Besides the uses I have thus briefly and, I am afraid, somewhat imperfectly set before you, there are many others to which the metal may be applied, for instance, joining iron to stone or wood, the tensile strain of the metal being from 650 lbs. to the square inch five minutes after setting. For joining railings to stone it would answer equally as well as lead, and cost very much less; also for coating the holds of ships. I have been told that an Act of Parliament has been passed by which builders are compelled, if the district surveyors desire, to cover the walls of houses after they are built 2 ft. out of the ground, with some material to prevent the damp from rising. It seems to me that Spence's metal is peculiarly adapted for this purpose.

I will illustrate to you some of the other uses to which this metal may be put. For hermetically sealing bottles; for covering cloth; for covering parcels that are being sent out to hot climates, thus obviating the use of lined boxes; for preserving fruit, or other articles of consumption; and I may state that experiments on a large scale are still being carried on at Mr. Spence's works, Belvedere, Kent.

I feel sure we have not yet come to the end of all the uses this Spence's metal may be put to, but I trust that I have shown you sufficient to induce you and others who may be interested in this discovery to make further investigations. If my paper is somewhat shorter than is usual, it is to some extent owing to my hesitation to make any statement which either Mr. Spence or I have not verified by actual experiment ourselves. I have already shown you a few of them, viz., casting on glass, casting an engraving, casting in metal moulds, casting in plaster moulds, casting in gelatine, resistance to atmospheric action, resistance to acids, resistance to acids as compared to bronze or marble, and uses in gas and water works. In conclusion, I express a hope that I have established the proposition with which I started, and I trust you are satisfied that this Spence's metal is a discovery which has a prospect of much utility to the fine and industrial arts, and that I have been justified in bringing it before the attention of the members of the Society.

DYNAMO-ELECTRIC MACHINES.

From "Engineering."

II.

We are now prepared to discuss the various systems of winding a Siemens armature. The actual system adopted by Von Alteneck and Siemens is a little complicated. In attempting to explain its nature, M. Breguet devised a simpler system so closely resembling it that he at first thought it identical. He took a single stout wire and bent it up in the manner represented in Fig. 12, the two ends being soldered to one another, and

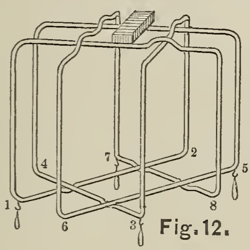


Fig. 12.

the separate bends so insulated as not to touch one another where they cross. Four little contact pieces were added at the corners 1, 3, 5 and 7, to dip into mercury cups like those of the preceding apparatus, but with quadrantal sectors, as in Fig. 10. Now here the whole current obviously traverses each branch of the conductor, and the rotation will take place with more than redoubled energy;

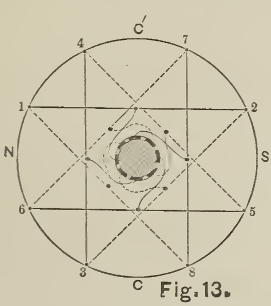


Fig. 13.

for the impulses will last during a whole quarter of a revolution, and there will always be two wires attracted, and two repelled by each pole of the magnet. The same system is represented diagrammatically in Fig. 13, where, however, a metallic collar slit into eight portions is supposed to replace the little contact pieces used for dipping into mercury cups. Of course more than eight vertical wires might be employed. Any regular polygon having an even number of sides would answer; but the octagon with star-like points is very simple and effective, and answers all purposes. As before, each single wire of the simple experimental apparatus may be replaced by a coil of many turns; and the whole may be wound upon a longitudinal cylinder or core.

The actual method of winding up the bobbin of a Siemens generator—the method invented by Herr von Alteneck—is represented in a similar diagram in Fig. 14; from which it will be seen that the arrangement adopted has sixteen

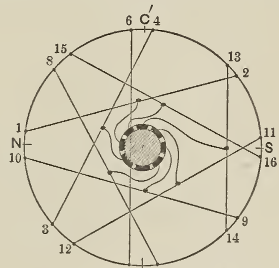


Fig. 14.

vertical conductors, and that it is an unsymmetrical one.

Curiously enough, a German engineer, Her Frölich, who, like M. Breguet, intended to describe the Siemens (or Von Alteneck) armature, discovered another system of winding up the wires, which is shown in diagram in Fig. 15. Here also there are sixteen vertical conductors arranged in pairs at the point of a regular octagon, and crossing the octagon by the diagonals at one end of the armature and by long chords crossing in the form of an eight-pointed star at the other.

There are, in fact, a large variety of ways of winding that coils upon a longitudinal armature, of which that adopted by Siemens is one, and not the best one.

M. Breguet says he has found no fewer than eight. Of these there is one which

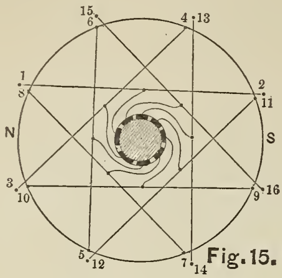


Fig. 15.

appears to be better than all the others. It is represented in Fig. 16. Its superiority consists in requiring the employment of a shorter length of wire to attain the same effects; which of course means not only a reduction of first cost, but a saving in the wasteful heating effects of

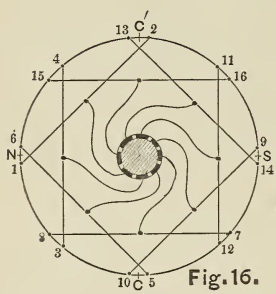


Fig. 16.

internal resistance. In this system the portions of the coils which cross the ends of the armature to unite the sixteen vertical wires cross the octagon along short chords. As these end portions of the coils contribute little or nothing tö the effective work of the motor or generator it is a clear advantage that they should be as short as possible. M. Breguet has given the following as a Table of the proportional lengths of wire necessary to make up end portions of equal sized armatures on the four systems:

System of Herr Frölich (Fig. 15)........	30.8
" Von Alteneck and Siemens (Fig. 14)..........................	30.5
System devised by M. Breguet (Fig. 13)..	28.4
" " " (Fig. 16)..	26.0

From which it appears that the last described arrangement is superior to all the others. Mr. Edison's latest generator is simply outwardly a Siemens armature placed between the two checks of a powerful upright electro-magnet. It is not known yet what system of winding up of the wire he has adopted; though the armature possesses one peculiarity in having a number of strands of iron wire wound traversely between metal checks around the core, and the longitudinal coils of insulated conducting wire are wound on outside.

To this elegant investigation of M. Breguet there only remains one point to add, and it will form a fitting peg on which to hang our next and concluding article on the theory of the Gramme machine, namely, that the power of all these machines can be increased not only by increasing the number of turns of wire, and arranging them as advantageously as possible, but by increasing the intensity of the magnetic field in which they move by introducing iron cores into the very middle of the coils.

III.

In the two preceding articles we have explained the beautiful and simple illustrations devised by Monsieur Antoine Breguet in his researches upon dynamo-electric machines. The first of these dealt with general principles underlying all machines for generating electric currents by the rotation of conducting wires in a magnetic field. The second was devoted to the Siemens machine and the various possible systems, good and bad, of winding the wire upon the armature. We have now to approach by far the most important part of M. Breguet's work, and to explain his theory of the Gramme machine, the only theory which completely accounts for the action of the ring of iron in the armature. We shall in conclusion give some further considerations of extreme importance upon a fact known to all practical electrical engineers, but hitherto completely unexplained by theory, namely, that it is necessary to displace the commutator brushes of dynamo-electric machines from the position of symmetry, the angular displacement varying with the velocity of rotation, and with the work which is being done by the machine.

Suppose, firstly, that a wire bent in the form shown in Fig. 17 was placed upon the apparatus described in the preceding articles and illustrated in Figs. 4 and 8, on pages 342 and 344. Under what conditions can it rotate? If a current passes through this wire, it will ascend branches 1 and 3 and descend branches 2 and 4. It is clear that there will be a tendency to move 2 in an opposite direction to 1; hence the forces tending to drive the conductor round will be two couples acting in opposite senses, urging 1 and 4 in one direction, and 2 and 3 in the other direction round the axis. The couple 2

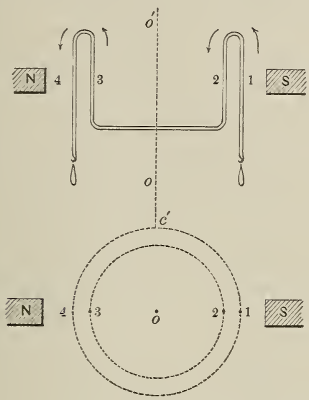


Fig. 17.

and 3 will be, however, the weaker of the two, since the length between 2 and 3 is less, and they are further removed from the most intense part of the magnetic field than are 1 and 4. The total force of rotation will clearly be the difference of the two opposing couples; and the arrangement, as it is, is evidently worse than the arrangement given in Fig. 4 of the first article. The rotation of conductors 1 and 4 is just *pro tanto* hindered by the opposing forces on 2 and 3. If only the action of the magnetic field on these two branches could be reduced to nothing, the effective force of rotation will obviously be increased. Now there is one way, and but one, to *screen off* the magnetic field from the branches 2 and 3, and that is by interposing a screen of iron in the form of a ring. To understand fully how the iron ring can act as a magnetic screen for the wires within it, it is needful to comprehend the nature of magnetic substances in general in respect of their behavior as screens.

We have, in the first article, spoken of magnetic lines of force as Faraday defined them, and their properties. The most important of these properties in the present regard is that they pass by preference through a magnetic substance, which, so to speak, conducts them better. Iron is about a million times as magnetic as air, hence we find that the lines of force in a magnetic field are very greatly altered in form by the presence of a mass of iron, as they have a tendency to so arrange themselves that they may run as far as possible through iron and as little as possible through the air or the surrounding space. For example, if Fig. 18 represents the magnetic "field" between two poles N and S, in which also a hollow cylinder of iron has been placed, it is found, by the method of sprinkling iron filings over a card laid in the field, that instead of assuming the usual simple arcs passing across from one pole to the other, the lines of force are bent about in a remarkable manner. They curve round so as to meet the ring, travel along in the substance of the iron as far as possible, then emerge at the other side to curve round sharply into the other pole. *The entire space within the ring is destitute of lines of force* and is thus screened off from magnetic influences.

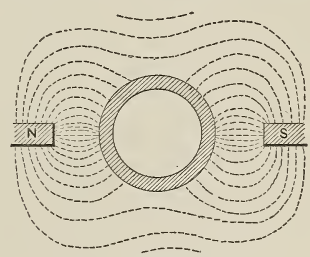


Fig. 18.

The interior of a hollow ball of iron is in like manner screened from all external magnetic influences; a property of which advantage was taken by Sir W. Thomson in the construction of certain galvanometers specially designed for use on board cable-laying ships. The cylinder of iron in Fig. 18 would serve equally well as a screen to the interior portions whether at rest or in rotation round its axis, for even if rotating the lines of force would prefer to pass through the iron rather than cross the interior air-filled space. The external field might be somewhat deformed in symmetry during the rotation, in consequence of iron requiring *time* to part with its magnetism, but this would not affect the interior space where no magnetic forces are.

It will be convenient for our purpose to consider the effects produced in the magnetic field by a cylinder of iron so short that it may practically be considered a *ring*. This is shown in section in Fig. 19. Here we may notice several

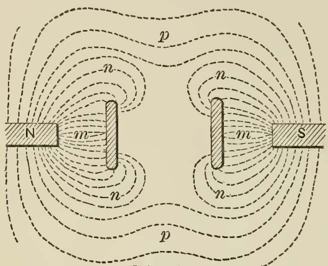


Fig. 19.

points. First the peculiar grouping of the lines of force. Most of them in the intensest parts of the field run straight from the pole to the ring, thence round through the iron of the ring invisibly, and emerge again at the opposite side. These groups of lines, marked m, indicate that the magnetic force is concentrated into that part of the field immediately opposite the poles. Nextly, there are certain groups n of less intensity which pass above or below the edges of the ring to curve round into it on the inner edge, and which in like manner run round the substance of the ring and emerge at the opposite side. Lastly, there are some outlying lines of force marked p which pass by above and below, and which are of no importance. It is particularly to be noticed that no lines

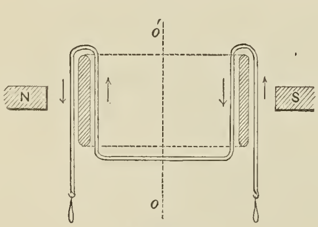


Fig. 20.

cross the interior of the ring to go from one pole to the other, so that the ring still acts as a screen.

Now suppose such a ring to be placed within the bent conductor of Fig. 17, the arrangement will assume the form shown in Fig. 20, where branches 1 and 4 of the conductors are exterior to the ring, 2 and 3 interior. Clearly, as far as 1 and 4 are concerned, they are more advantageously situated than before, for the iron ring intensifies the portion of the magnetic field in which they are situated. As to the branches 2 and 3, their condition is now wholly changed. They are chiefly screened from magnetic actions, the only lines that cross them being those of the groups b, but these lines instead of being merely lines of force, running across from N to S, are lines which actually curve round and cross them as if coming from S to N. Consequently the magnetic forces on 2 and 3 act in the reverse sense to what they did when there was no iron ring, and the force of rotation acting on 2 and 3 now tends to spin them round in the *same sense* as 1 and 4. The model illustrating this beautiful theoretical demonstration of the part played by the iron ring, was shown to the Société de Physique by M. Breguet at one of its meetings during

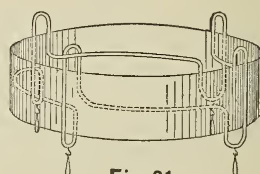


Fig. 21.

1879, and its performance was so perfect as to leave nothing to be desired. A further modification shown in Fig. 21, having four equidistant turns, is a still nearer approach to the Gramme ring. It only requires that a coil of many turns should be substituted for each single fold of wire, and that the number of such coils upon the iron ring should be increased, to obtain the true article. In that case, however, the commutator pieces would be made of small arc and proportionately numerous, as described in the preceding article. Up to this point we have treated the matter as if the Gramme armature were intended to rotate as in an electro-motor, converting an existing electric current into motion. The principle of *reversibility* laid down in our first article shows, however, that all the considerations advanced apply equally well to the case in which the motion of the armature in the field is employed to generate a current of electricity. As is well known, the Gramme machine, besides being an admirable generator, is capable of being advantageously used as an electro-motor. It matters not, moreover, from a theoretical point of view, whether or not the iron ring is fixed, or rotates with the coils of wire upon it; though for practical reasons the latter is of course always the case.

We are now prepared to discuss the question whether the Gramme armature with its ring, or the Siemens armature with its longitudinally wound coils, is the more advantageous. It will be admitted that the only effective portions of the coils of the Siemens armature are the wires parallel to the axis of rotation, and that those portions which cross the ends radially are comparatively useless, as they cut few lines of force, and add to the total resistance. Also, in the Gramme armature the effective portions of the coils are those external to the ring, the wires along the screened internal face cutting few lines of force. Hence, given two rival machines having equally intense magnetic fields, equal velocities of rotation, and therefore equal electro-motive forces, that machine will have the advantage in which the shortest wire can be coiled into the greatest number of effective turns. It must be remembered that one turn of the Siemens armature corresponds to two turns on the Gramme armature taken at opposite points on one diameter of the ring. Hence, the calling the longitudinal dimension of either armature l, and its diameter d, the length of wire necessary to make one complete turn of the Siemens armature will be $2\ (l+d)$, while that necessary to make the equivalent two turns of the Gramme ring will be $4\ l$ (neglecting the thickness of the iron ring, which may be relatively small). Hence, the Gramme will be better if $4\ l$ is less than $2\ (l+d)$; the Siemens better if $4\ l$ is greater. If $4\ l=2\ (l+d)$, or if $l=d$, then they will be of equal power. Hence, it follows that of necessity the Siemens armature should be long in proportion to its diametral thickness, while the Gramme will be best if the diameter of the ring be greater than its thickness parallel to the axis. For reasons of construction it is also found advisable to make the rings of the Gramme machine flat wide rings rather than deep narrow ones.

We will now finally follow M. Breguet into his inquiry into the cause of the dissymmetrical position of the commutator brushes of dynamo-electric machines. Experience has dictated that to obtain the best possible results it is necessary to adjust the brushes which take the current from the commutator to an oblique position, different from that dictated by theory. Moreover, the amount of this angular displacement is found to vary with different speeds of the machine, and with the work done in the circuit. Neglect of this matter leads to sparking at the commutators and consequent wear and waste. In the Brush machine and in the Weston, and some other forms, there is indeed a particular adjustment to enable the brushes to be set at will. Another point which has hitherto been quite unexplained is that if the machine were being employed as a generator of currents, this displacement of the brushes

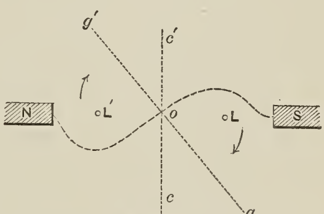


Fig. 22.

must be a lead, or a displacement in the direction of the rotation, while in the case in which the machine was used as a motor, the brushes must be displaced in the opposite direction to that of the rotation, or with a negative lead. In spite of these plainly incompatible conditions it has always been customary to attribute the practice thus dictated empirically by experience to the slowness with which the soft iron of the armatures loses its magnetism, or in other words to the retardation of demagnetization. If we go back to the simplest of all the forms of movable rotating conductor we have considered, it will be apparent that the best moment for changing the direction of the current in the conductor is that instant when perpendicular common to the conductor and to the effective lines of force in the field passes through the axis of rotation. Thus in Fig. 22, if the lines of force ran straight across the field from pole N to pole S, then clearly the best points to reverse the current would be at c and cl, or on a diameter at right angles to NS. Now, up to this point it has been *assumed* that the magnetic field is symmetrical across between the poles, and that the greatest number of effective lines of force run across straight from N to S, or at least in gentle arcs symmetrically above and below the line N S. As a matter of fact this is never the case, since the presence of the conductors carrying the vertical currents is sufficient to introduce serious modifications in the positions of the lines of force. Around the conductors which carry the electric currents there is also a "field" of magnetic force in which the lines of force are arranged, not radially as about the poles of magnets but in concentric circles. The presence of the current then changes the total directions of the forces at work in the field, and throws the lines of force into new places. In fact, as mentioned in our first article, the principal lines running across the field from N to S will be distorted, as shown in Fig. 22 into an S-shape, illustrating unmistakably the tendency to move in opposite directions the conductors L′ and L, in which the current is flowing in opposite ways. From the principle laid down above, it follows that the most advantageous position to reverse the current is, therefore, not along the diameter $c\ c'$, but along the diameter $g\ g'$, drawn at right angles to the chief line of force at the center. The angle between these two diameters is clearly the angle at which the contact brushes ought to be displaced, in order that the current may be reversed at the most favorable moment. We are here considering the case where a current is being used to produce motion, that is to say, where the Gramme machine is being used *as a motor*. Now the form of the S-shaped line will depend on the relative strengths of that part of magnetism in the field due to the field magnets N S, and that due to the current. If the current is relatively weaker, the S-shaped curve will be more nearly a straight line, if the current be powerful (relatively to the magnets) then the line running from N to S will be a well-formed S. Now, this clearly implies that if the current is strong, relatively to the magnet, the angular displacement of the contact brushes, $c'\ o\ g'$, will be great, while, if the current is relatively weak, the displacement of the brushes will be small. Again, it is well known that when an electro-motor is running with a great velocity there is a reaction current set up in it in an opposite direction to that which produces the motion and tending to produce an opposing electro-motive force. If an electro-motor is allowed to run very rapidly this opposing induced current will reduce the supplied current to a fraction of its original strength. The maximum work is done by an electro-motor when this reaction current just halves the original current. Hence, if an electro-motor whose armature is running in an invariable magnetic field be doing light work, and therefore be running very quickly, the reaction current will reduce the total current in the conductors relatively to the power of the magnets, and under such circumstances, the displacement of the contact brushes will be small. If the motor be doing heavy work, and its velocity be therefore slow, the reaction current will be feeble and the total current strong in proportion to the magnets, hence the brushes must be displaced through a large angle. The rule, therefore, for dynamo-electric machines used as *motors* is that the contact brushes must be displaced in an inverse sense to that of the rotation of the armature, and with an angular displacement, which is greater as its velocity is less, or as the work done by the motor is greater.

Now consider the case where the machine is used as a generator. If the armature be driven round in the field mechanically, the current generated will be in the opposite direction to that of a current which we have supposed to produce a rotation in the same sense. Hence, if we think of the magnetic forces due to the current thus induced in the conductors we shall see that they will produce a displacement of the lines of force in the field, but this displacement will be the converse of the former case; the chief line of force crossing the center of the field will be S-shaped as before, but will be reversed in position as compared with that shown in Fig. 22, and will pass from N above L′ below L, and so to S. In this case the diameter of commutation $g'\ g$ will cross the line $c'\ c$ from right to left, and the contact brushes must be displaced in the same sense, as the rotation of the armature, or must be set so as to have a true lead. Here again the question of the relative strength of the magnetic forces due to the current and to the magnets comes into play. If the field magnets be simply permanent steel magnets, or if they are electro-magnets excited by a current generated independently from another source, then the electromotive force in the rotating armature will be, as shown by the researches of Mascart and Angot, and others, simply proportional to the velocity of rotation. In that case, if the resistance of the circuit is constant, the strength of the current will also rise proportionally to the velocity and the deformations of the field, and hence the angular displacement of the contact brushes must be greater as the velocity is greater. The rule is, therefore, for magneto-electric machines, and for those dynamo-electric machines in which the field magnets are separately excited, when used as generators, that the contact brushes must be displaced in the same sense as that of the rotation, and with an angular displacement which is greater as the velocity is greater.

Finally, take the more common case where the field magnets of the dynamo-electric generator are excited by the current generated, or are included in the circuit of the machine. With small velocities before the electro-magnets have nearly attained their maximum magnetization, the strength of the magnets will increase as the strength of the current. Hence the relative intensities of magnets and of current grow almost at the same rate, and the displacement of the contact brushes need only be small. With greater velocities, however, and stronger currents, the magnets will begin to approach their condition of saturation, when any increase in the strength of the current no longer produces anything like a corresponding increase in the power of the magnets. Under such circumstances it is clear the deformation of the lines of the field will become greatly exaggerated, and the displacement of the contact brushes must be very great. M. Breguet tells us that with magnets too small in proportion to the armature, and with a velocity of 1770 revolutions per minute, he has succeeded in obtaining conditions which necessitated that the contact brushes should have a lead of 70°. A simple calculation leads to the conclusion that for great velocities the tangent of the angle of the lead should be proportional to the number of revolutions per minute.

Before entirely quitting the subject, we will just state what part is really played in this phenomenon of dissymmetry of commutation by the tardiness of the iron ring in receiving or parting with its magnetism. The presence of the iron ring exercises two influences quite distinct from one another. Firstly, since it requires time to magnetize or demagnetize it, it will necessitate that the contact brushes be displaced a little in advance of their theoretical position, or with an increased lead. This displacement, always in the sense of the rotation, will, therefore, diminish the total displacement where the machine is used as a motor, but will increase it where used as a generator. In either case, however, its influence is quite small. M. Breguet found experimentally that even with the enormous speed of 1770 revolutions per minute the displacement due to this source did not exceed 10°. Secondly, the presence of the iron ring increases the intensity of the magnetic field, concentrating a greater number of lines of force in it, and, therefore, tending to reduce the deformation in its symmetry. This is a most important influence, and it will be seen that in the case where the machine is used as a generator the presence of iron in the armature tends to bring back the most favorable position of the contact brushes towards the position of symmetry, that is, tends to *diminish* the angular displacement which must otherwise be observed. The action of the iron of the ring is, therefore, absolutely the contrary to that commonly attributed to it; for, so far from necessitating a displacement of the contact brushes in the direction of the rotation, it absolutely serves to diminish, and that very considerably, the angular displacement necessitated by the dissymmetry of the magnetic field.

The researches of M. Breguet place the whole theory of the Gramme machine in a new and intelligible light. They not only clear up the discrepancies hitherto existing, but lay down the basis upon which all future dynamo-electric machines must be constructed. The part played by the iron ring as a magnetic screen comes now for the first time to light; and by the aid of the reasonings now put forward one begins to see the *rationale* of many details hitherto dictated only by empirical practice. It is to be hoped that practical electricians will not be slow in turning these careful and ingenious deductions to good account.

THE SEWAGE OF LONDON.

From "Nature."

General Scott, in his recent paper at the Society of Arts, entitled "Suggestions for Dealing with the Sewage of London," deserves credit for having drawn attention to a subject which in itself must have especial interest for all residents in the metropolis, but which, from the manner in which he has dealt with it, possesses further attractions for those who have made the scientific aspects of the sewage question their study, in that he has really attacked this much-debated problem in an entirely new direction, and has in so far entered upon fresh ground. We do not remember that any previous investigator has set himself the task of examinining into the composition and character of the suspended matters of water-carried sewage, coupled with the possibility of the mechanical separation by simple subsidence (1) of the heavier mineral particles of the detritus, and (2) of the lighter flocculent particles; which latter, consisting as they do mainly of the fecal matters, possess a far higher manurial value than the heavier substances washed from the roads and pavements.

The sludge deposited from sewage by one or the other systems of precipitation has received hitherto the chief share of attention from scientific men, and even when the possibility of recovering the solid matters in sewage by some system of straining or rude filtration, or the retention of such solids in tanks in which the sewage is brought to temporary quiescence, has been considered, it seems on all occasions to have been the practice to regard the entire bulk of such deposits as an inseparable compound of very low value from the manure point of view. It is, of course, the manurial value of the ingredients contained in suspension and in solution in sewage which has been so frequently inquired into by chemists; and, beginning with the report of Dr. Hoffman and Mr. Witt in 1857, down to that of Messrs. Rawlinson and Read in 1876, a vast mass of valuable information concerning the nature, composition and value of the manurial elements of town sewage has been accumulated. It has remained for General Scott to point out that—

1. A very large proportion of the solid suspended matters may be removed from sewage by simple subsidence.

2. That such matters may roughly be separated, the more valuable from the valueless, by the method in which such subsidence is accomplished.

3. That after such preliminary treatment, any chemical process for the clarification and partial precipitation of the dissolved impurities of sewage may be carried out far more readily, and under conditions rendering their success in an economical point of view one of greatly increased probability.

4. General Scott has indicated various simple methods for dealing with the silt and detritus removed from the sewage at a relatively small expense; of deodorizing and fitting the sludge obtained by subsidence for the manufacture of a manure; and lastly, a mode of further purifying the London sewage by a system of chemical treatment whereby it may be rendered suitable for discharge into a river of large volume.

Assuming the dissolved impurities to be incapable of recovery unless the sewage water can be utilized for irrigation, the first object of General Scott's paper was to show how large an amount of harm was done to rivers and the dwellers on their banks solely by the solid matters contained in sewage. By means of extracts from the reports of the various Royal Commissions who have examined into this question, and the information furnished to the Metropolitan Board of Works by their own advisers, Messrs.

Bidder, Hawksley and Bazalgette, he proved that the deposits in the river, the mud banks, the foul emanations from which were most unhealthy, and the dangers to navigation, were all due to the discharge of the solid ingredients of raw sewage into rivers and into the Thames.

General Scott next entered very minutely into the composition of the suspended matters of sewage. An estimate of the total weight of solid matters due to a mixed population of 3,500,000 persons, with a proportionate allowance for the fertilizers existing in the excreta of animals, together with the *débris* of the animal and vegetable substances which might find their way into the sewers, would manifestly represent the sum total of the organic matters in London sewage.

Concerning the gross annual amount of organic matters, different estimates appear to vary very slightly, and in assuming them in the case of London at 50,000 tons per annum, there would seem to be but a small margin for error; the quantities of detritus, however, have been very differently stated by the various authorities. From the most reliable analyses of the London sewage, taken at all periods of the day and night, and in many different parts of the metropolis, there appears to be a tolerable unanimity in assigning the ratio of the organic to the mineral ingredient of the suspended matters to be as 1 is to 2. After a period of settlement, it is found that the proportion is, by the subsidence of the heavier mineral particles, exactly reversed, as the larger portion of these valueless components of sewage impurities rapidly subside, entangling with them about one-fifth of the organic matters in suspension. General Scott proposes, therefore, a double system of tanks. The first set would consist of a series of shallow catch-pits, in which the sewage will only be brought to a state of partial repose, and in which it will part with about four-fifths of the solid mineral matters and one-fifth of the organic matter. In the second set of tanks, in which more time will be given for the settlement of the matters in suspension, the sewage will be deprived of nearly all the remaining suspended impurities, namely, one-fifth of the mineral and four-fifths of the organic matters. If we assume the gross weight of the organic matters at 50,000 tons per annum, the mineral ingredients will, according to the analyses quoted by General Scott, equal 100,000 tons, and the total of 150,000 tons thus obtained is, in reality, a very low estimate of the amount of the suspended matters in London sewage. These matters, General Scott is of opinion, he could roughly separate in his tanks thus: In the detritus tanks he would obtain 80,000 tons of mineral matters, together with 10,000 tons of organic matters; in the second set of tanks he would expect to find about 20,000 tons of mineral matters mixed with about 40,000 tons of organic matters. The exact percentage composition of this latter sludge would, he believes, after studying and comparing many analyses and valuations, be somewhat as follows:

Organic matter (without nitrogene)	66.50
Nitrogene	3.50
Phosphoric acid 2.80 = tribasic calcic phosphate	6.07
Potash	1.25
Sand and inert mineral matter	22.68
	100.00

In the debate which took place after the paper, Dr. Frankland, while admitting General Scott's process "worthy of trial," took exception to this estimate, and maintained that his experience was "that after the separation of detritus from London sewage, the maximum percentage of organic matter was 63, whilst the minimum was 21, the average being 39½, and these high percentages were obtained under exceptionally favorable circumstances, because, in the collection of these samples of sewage, little or none of the so-called detritus was mixed with it at all." He further stated that "he did not think it would be safe to calculate on more than 33 per cent. of organic matter in the dry sludge." This question of the possibility or otherwise of effecting a separation more or less perfect, of the mineral from the organic elements of the sludge lies at the root of General Scott's proposals, and while giving all due weight to Dr. Frankland's high authority, we are compelled to admit that General Scott's figures, many of them based on the analyses of Dr. Frankland himself, seem to point in the opposite direction to that pointed out by Dr. Frankland, as concerns the relative proportion of the mineral and the organic matters after settlement.

The question to be decided is, admitting the composition of the sewage solid to be in the first instance 2 mineral to 1 organic, can we reduce this proportion to 2 organic to 1 mineral, by bringing the sewage to a state of quiescence in tanks? This could be tried on a sufficiently large scale to settle the point at issue in a very short time, and it is a question which to a great extent depends upon the result of actual experiment on a large scale, it is certainly one for the officers of the Metropolitan Board of Works to decide.

Passing over the theoretical values of the deposits based upon their contents in nitrogen, phosphoric acid and potash, which General Scott has dealt with very carefully, we come to the question of deodorizing the sludge and its preparation as a manure. For the former purpose the employment of slaked lime is advocated, used in the small quantity of only .66, or less than 1 per cent. of the total weight of the sludge. This slaked lime, made into milk of lime by the addition of water, is to be thoroughly incorporated with the sewage deposit, and a sufficient amount of crude superphosphate is then to be added, in order nearly, but not quite, to neutralize the lime. A crystalline precipitate of phosphate of lime is thus formed in the sludge, which greatly aids in the drying of the compound, or, to put it more correctly, facilitates the extraction of the water. Some of those who took part in the debate doubted whether General Scott, in his estimate of 20s. per ton on the dried material, which included the cost of chemical treatment, had made a sufficient allowance for the great labor and difficulty which would have to be incurred in drying the sludge for use as a manure. Dr. Voelcker, who pointed out that "he had gone very carefully into the figures in the paper, and was very glad to find that General Scott had avoided those exaggerations which frequently disfigured calculations of this kind," quoted some observations he had made tending to show that sewage sludge parted with water with extreme difficulty, though he admitted that after treatment with lime and phosphoric acid such sludge would dry with greater rapidity. In the various forms of filter presses now largely used for drying clay slip and expressing precipitates, very great improvements have recently been effected, and it has been stated on good authority that it becomes possible by their use to reduce the moisture in such materials as low as 50 per cent. There still remains, however, a large proportion of water to expel, and, as Dr. Voelcker stated, this can only be accomplished by means of artificial heat.

The question of the cost of drying sludge is one which possesses many features of interest, and the entire subject would be one well worthy of the special consideration of the Society of Arts at their annual conference on the treatment of sewage. We should like to have devoted more time to the calculations of General Scott of the theoretical value of the three chief fertilizers present in sludge, viz., nitrogene, phosphoric acid and potash, as also to the expense of preparing soluble phosphoric acid, concerning which latter point Dr. Voelcker threw out some valuable suggestions during the discussion, but we must now conclude. We entirely agree with General Scott in his denunciation of the folly and imprudence of continuing to cast raw sewage into the Thames; he has certainly pointed out a way of greatly abating the present evil, and as the plan he advocates could be tried upon a sufficient scale at an almost nominal expense, we feel justified in urging with Dr. Frankland that this should be done, and we cordially echo his concluding observation "that the Board of Works have no right to look for a profit in getting rid of the objectionable matter. If they can succeed in doing it without a loss or at a cost not greater than that involved in dredging it out of the river again, it ought to be done; because if sewage mud is deposited in the river there must be an obstruction to navigation, besides the putrefaction of organic matters which, when deposited on the banks of a tidal estuary, become very offensive, especially in warm weather."

So far as one can judge from the facts adduced by General Scott, his scheme promises to be more efficient for the ends aimed at than any hitherto proposed, and certainly it seems to us that the great scientific principles which are applicable to the subject have been kept well in view. And from our standpoint this must be the test of the efficiency of any scheme for the disposal of sewage. We fear that hitherto those with whom the decision rests as to what scheme shall be adopted for the disposal of the sewage of London have looked upon the question too much as one between rival "schemes," and considered far too much the supposed interests of rival "bodies," and too little the clear teachings of science and the welfare of the public. It is evident that for London, at least, the whole subject of the disposal of sewage will have very soon to be reconsidered, and we trust that the authorities concerned will take into their council reputable chemists and physicists, who, we are sure, can have no interests more at heart than to see the unmistakeable teachings of science practically applied to the salvation of society.

CARBON, CRYSTALS AND SILICON.

By the Rev. J. C. BROWN, LL. D.

From the "Journal of Forestry.

THE success of Mr. James Mactear and of Mr. Robert S. Baxter in procuring crystals from carbon—the report of Mr. Maskelyne that some of those submitted to him for examination were not crystallized carbon, but some crystallized silicates—and the statement of Mr. Mactear that some of them consist entirely of silica and alumina with a little magnesia, recall a like discovery, with like results, which excited like interest some forty years ago, some people rejoicing in the light likely to be thus thrown upon the atomic condition of so-called elements, and others ridiculing the alleged discovery, and the supposition that it would lead to further discoveries in the direction indicated. About that time Dr. Samuel Brown obtained, in the course of experiments in which he was engaged, some beautiful crystals which were considered by him, and associates in his work, crystallized carbon, such as the diamond; and great was the joy which was thus produced. What Mr. Maskelyne describes in his report as "the problem of the permutation of carbon from its ordinary opaque black condition into that in which it occurs in nature as the limpid crystal of the diamond," seemed to have been solved, and solved by him.

Subsequent examination and experiment satisfied him, however, that these crystals were not artificial diamonds, but, to use again the words of Mr. Maskelyne "some crystallized silicate," as it seemed to him pure silicon, or crystals of quartz; and the full significance of this was realized by him at once. If these were silicates, and no silex had found its way into the material whence they were produced, then silex had been formed of carbon,—one of the substances considered as a simple element had been formed of another substance considered as a different simple element: a veritable transmutation of one *quasi*-element into another had occurred.

Let it be noted, however, that there is an important assumption here—an assumption the full importance of which perhaps none but a chemist can fully realize—the assumption embodied in the statement *if no silex had found its way into the material from which the crystals were produced.* On this point he had no doubt; but he labored—labored long and labored hard—to devise other processes, which should satisfy others that all access of silicate had been effectually prevented. And whenever a possible source of error was discovered by himself, or by friend or foe, he set himself at once to devise yet another process by which proof could be given that not thus had the crystals been produced.

Partly with a view to protect his discovery, partly with a view to testing it, and partly in prosecution of the course of discovery upon which he had entered, he applied his method of investigation to others of the so-called elements, and with like success.

His procedure was not empirical,

but was based on views admitting of explicit statement, and was carried out on principles well defined.

His general views of the atomic constitution of matter, similar to those of Boscovich, are given in a posthumous work entitled "Lectures on the Atomic Theory, and Essays Scientific and Literary."

These lectures, delivered before a select audience in Edinburgh in 1843, excited much interest amongst thinking men by whom they were attended. Dr. Chalmers, Lord Jeffrey, and Sir William Hamilton were, I believe, amongst those of them who afterwards publicly expressed their interest in the views advanced.

His working hypothesis was that the so-called elements are each of them composed of atoms of elements of more simple composition. The atomic theory of Boscovich admits of a conception of such an hypothesis being grafted upon it; and the isomerism of cyanogen and paracyanogen, of oxygen and ozone, may be referred to in illustration of what is meant.

The view taken of the atomic constitution of any of the so-called elements precluded any hope of being able by analysis to reduce a more complex one to its constituents, but left open to experiment the application of any device for synthetically producing the more complex out of the more simple. This he sought to effect by bringing atoms of the more simple, in a nascent condition, within the sphere of each other's chemical attraction; and this he effected with more than one of the metals. Of this fact he made no secret; but he deemed it inexpedient to widen a controversy which was produced by the publication of his first discovery, which was that to which I have referred.

It appears to have been in the beginning of 1834, while attending Dr. Hope's lectures on chemistry in the University of Edinburgh, that he first caught the idea of the possibility of producing the diamond from amorphous charcoal. In the course of experiments thus suggested he succeeded in producing a beautiful crystal in 1836, while engaged in endeavoring to solve laws regulating the process of crystallization. Information of this was communicated to two of his fellow-students with whom he was working, and to Dr. Christison, in whose laboratory they were at work; and there opened upon him a far-reaching vista of research. It seemed to be a diamond; but that was not all; and, as has been stated, subsequent research satisfied him that similar crystals which he obtained were not diamonds, as many of his fellow-students, who had heard vague accounts of what he had accomplished, boastingly alleged. Under the date of 19th October, 1838, he wrote to his sister, "These crystals must have been siliciurets produced by the transmutation of carbon into silicon." And the results of his experiments he embodied in a paper which he read to the Hunterian Society early in the session. He graduated as Doctor in Medicine the following year; and his thesis was entitled "Chemical Fragments, and Carburets and their Crystallization, &c.;" and for this he was awarded one of the gold medals given by The Faculty.

In both of these he gave explicit statements of his views as held at that time. They may be crude, as I have heard them characterized, and, as I am told, he himself afterwards considered them; but they are not without interest as indicative of the progress of research; and the experiments detailed may be found not without value, as suggestive of what may be done, or as supplying data of negative, if not of positive importance.

He was suffering from incipient disease, and he was feeling depressed by grief, and to some extent distracted by business, consequent on the death of his father, and of a beloved friend, while he prosecuted his subsequent researches; but he ceased not till satisfied beyond all doubt of the reality of his discovery. Writing of this to a friend, he said, "I doubted, and feared, and trembled at my discovery, till a fiftieth uncorruptible witness gave me assurance that nature had not indeed deceived me on that eventful night."

To another he wrote under the same date, 27th June, 1840, "During the last six weeks I have changed given weights of cyanogen, carbon, tin, lead, and silver into the same weight of paracyanogen, silicon, lead, mercury, and gold;" and by the close of the year he had arranged several of the so-called elements in isomeric groups.

His first public announcement of such results obtained by him was a paper, "On the Preparation of Paracyanogen in large quantities, and on the Isomerism of Cyanogen and Paracyanogen," which was communicated to the Royal Society of Edinburgh by his friend and teacher, Sir Robert Christison, on the 15th of February following; and it was subsequently published in the fifteenth volume of the Transactions of the Society, which step was resolved on under a realizing view of what was implied in the measure, to which expression was given by Principal Forbes in the statement, "The interests of the Society are now at stake." The selection of the subject was made—not on the ground of its relative importance, but in view of the controversy which he foresaw must ensue on the publication of his discoveries, and the facilities which this supplied for easily and thoroughly testing the principles involved.

In this paper are detailed various processes, the design of which as stated by him was "to decompose the bicyanuret of mercury at such a temperature, and under such a degree of pressure as to secure the simultaneous extrication of the two equivalents of cyanogen or their elements, in the expectation that they should come off united, and produce the interesting compound of nitrogen and carbon isomeric with cyanogen and paracyanogen, and that result was sought in the belief that it would illustrate the chemical theorem of the existence of bodies, which, though composed of the same elements in the same proportion, yet differ as widely from each other in chemical properties and mechanical conditions as one element differs from another."

The memoir was designed to be introductory to a second, in which the same method should be applied to substances recognized as essentially different, and considered as elementary, simple, undecomposed bodies, incapable of decomposition. This second, bearing the title "Researches on the Production of Silicon from Paracyanogen, with Details of Experiments and their Results," was read before the society on May 3, and with it was lodged a sealed paper containing information in regard to other processes whereby the transmutation of the so-called elements had been effected. After his death this packet was returned by the Society to his widow.

The statements in this memoir gave occasion for much comment and remark; and circumstances arose which gave occasion for greater keenness in some of those which subsequently were made. By some it was felt to be a subject which must be decided by experiment and not by disputation; and under this feeling Dr. George Wilson came forward and offered to repeat the experiments detailed, in company with Mr. J. C. Brown, Jr., a cousin of Dr. Brown, who was familiar with the method of experiment followed, and to report the results. They did so; and their report was submitted to the Royal Society, and published in their Transactions in, I think, the year 1844.

It appears that they considered the most satisfactory results would be obtained by quantitative analysis, and to this they gave their chief attention, but they failed to obtain satisfactory results. When they obtained the same material results obtained by Dr. Brown it was not in anything like the quantity in which he had done; nor did they always obtain this; nor could they tell why in some cases they succeeded and in others they failed.

The title of the paper is "An Account of a Repetition of Dr. Samuel Brown's Processes for the Conversion of Carbon into Silicon, by Dr. George Wilson and Mr. Croumbie Brown." It appears that:

1. They obtained silicon from bodies not containing that element, every precaution against the insinuation of silicon from any external source having been taken.

2. They never procured the whole weight of carbon employed in the shape of silicon.

3. They got sometimes more, sometimes less silicon, they could not tell why.

And it was argued by others—1st, the silicon must have been formed either from the carbon; or 2nd, from nitrogen existing in the materials employed; or, 3rd, from both: and in any case the appearance or formation of another of the so-called elements was put beyond dispute. With many experiments made by Dr. Brown there had been like varying results obtained. It was the one fact that silicon had been found which was essential. He considered he had reported processes which could not fail in competent hands. The fact that they had failed in the hands of Dr. Wilson and Mr. Brown showed that they came short of what he had supposed, and that his details had been deficient in explicitness; and he quickly set himself to devise, if possible, a crucial experiment which could not fail in the hand of a competent chemist, and in which the presence of silicon in the product obtained could not possibly be accounted for, on the supposition that it had been produced otherwise than from carbon employed. But he died before such a crucial experiment could be discovered.

His life was prolonged for years. Many of them were years of suffering.

Processes were devised which made those which he had published appear crude—correct, but crude; and in the year 1853, during a period of bodily depression, he gave expression to a passing thought that the crystals he had obtained from carbon might not be siliciurets after all; but never, excepting on that occasion, do I know of a doubt on the subject having been entertained by him.

The difficulty was not to devise other processes than those he had published by which like results might be obtained, but a crucial experiment—a process by which the fact could be established beyond all doubt or cavil. At length, on his death-bed, with quickened intellect he saw—or thought he saw—how this might be effected. And some little time before his death he said to the writer, "Could I but have three days of strength to rise and resume my work, it would be done." But his strength was gone.

In this stage the subject has remained ever since. It is stated that transmutation of one metal into another has occurred accidentally in America—that the same, or a like transmutation of one metal into another, has been effected in Europe—and that both in vegetation and in animal life phenomena have been observed which are in accordance with a supposition of a transmutation of *quasi* elements having been effected. And now the observations of Messrs. Mactear, Baxter, and Maskelyne prepare the way for reopening the question of forty years ago relative to the production of silicon from carbon.

THE WATER WORKS OF TOKIO, JAPAN.

By W. S. CHAPLIN.

Written for Van Nostrand's Magazine.

Three rivers enter the bay of Yeddo at its northwest corner, the Sumida, the Naka, and the Yeddo, the first being on the west. The land near and between their mouths and along the bay is but little higher than the water of the bay, and is probably of a very recent formation. Indeed maps made only two hundred years ago show that much of the district now occupied by the city of Tokio was then covered by the water. Geologists say that the whole region near the head of the bay is being raised at a rate of about one foot in a century, and, as the land is almost level, it seems probable that not very long ago this whole plain was under water.

West of the Sumida, now, the low plain abruptly terminates and a line of hills begins, which ends in a gently rolling plain that reaches back to the mountains, a distance of from twenty to thirty miles.

The city of Tokio covers the low land on both sides of the mouth of the Sumida and along the bay, and reaches back over the hills on to the higher plain beyond. It may easily be divided into two parts; the low part in which the surface is seldom more than ten feet above the mean level of the water in the bay, and in many places not more than five feet above it; and the high part, from forty to one hundred and twenty feet above the same level.

The low part is by far the more densely settled of the two. It is the business portion of the city. It is intersected by numerous canals, which afford easy communication with all the principal districts. The streets are narrow, from twelve to twenty feet wide, except the main street which is somewhat wider. There are as a rule no sidewalks, and drainage is provided for by narrow, shallow, open drains placed close to the houses on each side.

The higher part is occupied principally by dwellings, although the more important streets are lined by rows of shops.

The houses are as a rule one story high and built of wood in an extremely light style; but in the business quarter and along the main streets, there are many buildings two stories high and built in the way in which the Japanese build fireproof buildings. It may be interesting to describe these structures —called godowns by foreigners, kura by Japanese:

A foundation is made by either driving piles about six feet long, or by ramming large stones into the ground where the walls are to be. On this foundation a stone wall a foot or two high is built; and on this wall a heavy framework of wood is raised. The interstices of the framework are filled in with interlaced bamboo, and the whole is then covered with a layer of tenacious mud which has been dredged from the bottom of the canals or river. When this mud is dry another layer of mud is put on, the various layers being held together by strings which are fastened to the bamboos. After several coatings have been put on and the whole is thoroughly dry, a finishing layer of thin mortar is put on. Generally the mortar is colored black, and while it is hardening it is rubbed and polished so that the whole building is of a shiny jet black. The windows and doors are frameworks of wood covered with mud. Great care is taken to make the building air-tight. When in good repair, these buildings appear to be proof against Japanese fires, but it does not seem probable that they would resist the greater heat caused by the burning of the heavy buildings of foreign cities.

The water obtained from wells throughout the city is bad; near the bay it is brackish, while further inland it contains such impurities as to make it unfit for drinking purposes. In the high portion of the city the wells have to be made from forty to sixty feet deep, and even at that depth they afford but a limited supply.

The area of the city is 16.1 square miles, and it has 799,975 inhabitants and 219,307 buildings.

The city is provided with a system of water works which when it was built was as good as that of London, and much better than that of Paris. The facts which can now be obtained concerning the building of these waterworks are very meager, as the records are said to have been burned in a great fire which destroyed nearly all the city a few years after the works were completed. Yet as the Japanese methods of doing work are probably about the same now as they were then, we may easily replace what has been lost.

About ten miles back of the city, to the west, are three small lakes from which a canal was made to the city early in the seventeenth century. This canal, called the Kanda canal, could not have furnished a great amount of water, as the lakes are small and shallow and drain out an inconsiderable tract of land. Now they are filled with water plants, and look as if the water which comes from them must be very impure. The people living near them say they are supplied by springs, which is probably a fact as the water which comes from them in summer is quite cold.

It appears that the Kanda canal did not supply the quantity of water needed, as in 1653 another canal was made to bring to the city the water of the Tama river, which empties into Yeddo bay about eight miles south of Tokio.

This Tama canal begins at a point where the Tama river leaves the mountains and enters the plain. The works for turning the water into the canal are very simple, but seem to be sufficient. The river here when it is full is about six hundred feet wide and ten feet deep; but when the water is low the stream only occupies about one hundred feet on the northern side of the bed. When the water is high no dam is required; but when it is low, a temporary dam is made by placing heavy timber stringers at the surface of the water from the shore out to a crib-work pier, which is built in the stream, and then from this one along to two others. Upright pieces are placed about two feet apart on the up-stream side of the stringers, and against the uprights straw matting is placed. A few shovelfulls of earth thrown on the bottom of the matting make the dam tight. When the water rises and the dam is consequently not needed, the uprights and matting are carried down stream, and the stringers, which are fastened to the piers at one end, swing around so that the whole channel is open for the water. Labor is so cheap that it is doubtless more economical to replace the dam when necessary than it would be to build a permanent dam.

The line of the canal is so chosen that nearly its whole length it is in excavation; and this was not at all difficult as the plane is nearly level. In one place the water filled a shallow depression in the ground. It is said that it was then thought by the Japanese that the cherry tree absorbed poison from water; for this reason the banks of this small lake were lined with a row of cherry trees, which are still standing.

The banks of the canal are not protected in any way. The material of which it is made hardens under the influence of water, so that the banks are now nearly vertical and but very little worn by the water.

There are several branches from the canal which carry water for irrigation to many villages situated to the north of the canal, and other branches running southward back to the Tama, afford power to drive mills for cleaning rice and grinding flower. So much of the water is drawn off by these branches that only about one-fourth of what leaves the Tama reaches Tokio. A rough gauging near the head of the canal showed that 150,000,000 gallons daily entered the canal in the dry season of the year, and it is probable that only about 40,000,000 gallons go into the pipes of the city.

Near Tokio the two canals—the Tama and the Kanda—are connected, so that about one-half the supply of the Tama canal goes into the Kanda pipes.

Where the Tama canal enters the city there is a long masonry chamber, in which there are gratings for stopping floating bodies, and gates for shutting off the water. The Kanda canal formerly was open for some distance into the city, and as it is run through the middle of a street of course the water was much contaminated by surface drainage. This portion of the canal has, however, been lately covered with an arch. These two instances and a bridge by which the water is carried over the Kanda river are all the difficult works in the whole system.

The mains and pipes through the city were formerly made of wood; recently, however, stone conduits have been built in some streets, and a small quantity of iron pipe laid down, but wooden pipes are still mostly used in repairing and extending the system.

The small wooden pipes, say up to eight inches square inside, are made by cutting out a square timber so that it forms three sides of a box, and nailing on a plank for the fourth side.

The mains, which are sometimes two and a half feet square, are made of planks, which are fastened together by driving long spikes obliquely through the edge of one plank into the next. The joints are caulked with a fibrous bark. The pipes seem, when new, to be very tight. On the average these pipes last seven or eight years, but in some cases they have gone without repairs for more than one hundred years. In any other country the expense of making and replacing pipes would be enormous, but here, although the timber is all sawed by hand, and the smaller pipes are cut out with adzes, labor is so cheap that up to the present this system has been considered less expensive than it would be to use pipes and mains of iron.

When several pipes meet, or when it is desirable to reduce the size of the pipe, a large box is put into the ground, into the sides of which the pipes are introduced. These boxes generally reach above the surface of the ground, in a few cases as much as ten feet, and the tops are closed with heavy covers. Perhaps these boxes serve as depositing basins.

The water is not carried into the houses, as is the custom in other countries, but is delivered into what, for lack of a better name, we may call wells. These wells are made in exactly the same manner as the ordinary wells are, except that in some cases the bottom is closed. A hole three or four feet in diameter is excavated and lined with hooped wooden cylinders, somewhat as if a number of headless barrels were placed one on another from the bottom of the well to a height of two or three feet above the surface of the ground. The earth is packed in around the cylinders, and they last a long time. In some cases the well has a stone or cement top, but this is more for ornament than because it is of any value.

The connection between the pipes and the wells is formed by bamboos about two inches in diameter, out of which the septa have been broken. The depth of these wells seems to depend only on the quantity of water which is used from each well. The discharge through the bamboo tube is about uniform through the day, and is of course very small; so the well must contain a considerable part of the supply for a day; otherwise some of the users might have to wait for the water to run in. The wells are so slowly filled that in case of fire they are quickly emptied; the waterworks are consequently of but little value in extinguishing fires. Each well is usually surrounded by a narrow platform on which the rice and clothes of the neighborhood are washed.

The mains are carried across the canals by suspending them under the bridges. The bridge across the Kanda river, spoken of above, is a wooden box about four feet square, which reaches from bank to bank. It is about sixty feet long, and is supported at two points on piles. A grating placed at the entrance serves to arrest any floating body which may come down the Kanda canal.

The systems of pipes spoken of supply only that portion of the low part of the city which is west of the Sumida river, and only those districts in the high part of the city through which they necessarily go. On the eastern side of the Sumida there are no mains; and, as the water in the wells is brackish, drinking water is brought in boats from the mains on the western side of the river, or from the rivers at points above the limits of the tide. It is sold in the streets by the pailful at about one-eighth of a cent a gallon.

In order to appreciate the difficulties which the Japanese had to overcome in building these water works, we must take into consideration the tools with which they did the work. They did not have shovels, carts or pickaxes in making the excavations. To dig the earth they now use a long narrow hoe, the head of which is wood protected by a heavy iron edge and sides. If they wish merely to throw the earth out of the excavation, they first loosen it, then hoe it into a shallow basket, and then lift or carry the basket out and empty it. If they wish to carry the earth some distance they hoe it on to a mat, the diagonal corners of which are connected together by ropes; a pole is passed through the ropes, and two men, taking the pole on their shoulders, carry the earth away.

In making the pipes they must experience considerable difficulty, as the long slender spikes used cannot be driven, and they have no augurs. They use a tool which is especially made for driving in and pulling out again, and with this, after driving it in and loosening it several times, they get a hole so deep that the spike may be driven in its full length without bending.

The Tama canal is 28.9 miles long and has connected with it in the city 30.3 miles of pipes: the Kanda canal is, with its branches, 14 miles long, and has 29.1 miles of pipes. The pipes are connected with 8,000 wells.

In 1877 an examination of the water at various points in the city was made by Prof. Atkinson (see Transactions of the Asiatic Society, vol. 7, 1877). He found that the water, when it entered the city, was very pure; but that, as it ran on through the pipes, it was more and more contaminated, until, in the lower and most thickly settled part of the city, it contained a large percentage of impurities. The presence of these impurities might be explained either by a leakage of surface water into the pipes, by diffusion through the pipes, or by the flowing back into the pipes of water which had become impure in the wells. The last explanation seems to be most satisfactory, as the surface water in many cases does make its way into the wells, and there must be a re-discharge back into the pipes, during the hours when there is the greatest call for water, from those wells from which but little water is used.

The water works of Tokio cannot be cited as an example of what such works should be; they are interesting only as a specimen of engineering executed long ago, and wholly under Japanese supervision. At present they exhibit great defects, and doubtless before many years they will be replaced by a new system embodying all the improvements made in other countries, and spreading over the whole extent of this great city.

ARCHITECTURAL METAL-WORK.*

By T. W. TONKS.

From "The Building News."

The very position of a nation is held to be shown by how many thousand miles of iron rails it has laid down in comparison with the square mileage of its area; it is tested by how many millions of tons of iron it can produce annually, or by how many it can consume in its manufactures. The very rise or fall of a nation's prosperity is now gauged by the rise or fall of its production or consumption of iron, or by both taken together, and the rise or fall of many an Empire would be of less moment to the world at large than a great rise or fall in the value of iron per ton.

It was not to be expected that the architect would long remain unaffected by this potent factor in modern civilization. In the middle ages, iron had become recognized for quaint locks and quainter keys, for bolts and bars, for beautifully wrought hinges and rails. Then for elaborate gates, verandahs, furniture, and much subsidiary work; but it seems to have been reserved for the present century to apply iron in the main construction of a building. Huge girders, iron beams and supporting columns are now the rule in business architecture, and when we see the enormous weight of successive stories piled upon such slender pillars as we constantly meet in modern buildings, we are tempted to echo Mr. Ruskin's fears and warnings as to the probable fate of such erections. The adventurous spirit of nineteenth-century architecture has found in iron a fitting instrument for carrying out its wildest fancies. The Devonshire Conservatory, the Palace of Iron and Glass of 1851, the steeple of the Cathedral of Vienna, and the present Crystal Palace at Sydenham were successive achievements in this direction. Then the old stone bridge that spanned the river, with its many and picturesque arches, has given way to the marvelous Suspension Bridge, hanging almost like a fairy film in mid-air, as with the high-level Bridge at Newcastle-on-Tyne, and the Avon Bridge at Clifton. The exigencies of railway enterprise have given us many diverse instances, such as the Crumlin Viaduct and the Tubular Bridge over the Menai Straits. But, alas, in the unhappy instance of the Tay Bridge, near Dundee, we seem to have reached the limit of that adventurous architecture and engineering in iron, against which Mr. Ruskin so loudly and persistently declaims.

The dangers of corrosion and oxidation may to a certain extent be guarded against in iron construction; but there are always hidden risks arising from flaws or faults in casting, etc., which remain to be considered. It is very possible that as building construction, even in the question of the picturesque or beautiful, the single slender iron column as a support in the interiors of buildings is far inferior and but little less costly than a clustered column would be. In the early spring of last year I visited the Cathedral of Salisbury, that matchless example of the pure unmixed Gothic of England, and was struck immediately by the hint which the clustered columns of the interior gave to the architect in iron. The dark polished shafts of Purbeck marble, clustered round the lighter colored freestone columns, suggested iron in a moment by a curious association of ideas. The effect is stable, yet in the last degree graceful, and it seemed impossible to resist the conclusion that a similar cluster of iron columns, the center one

* Read before the Birmingham Architectural Association, February 24.

bolder than the rest, and not necessarily cylindrical, would be but little more costly than the single shaft. The extra cost would be more than repaid, I should opine, by the additional stability, and the relief to the eye and the mind would be enormous. Instead of the painful sense of inadequacy which the ordinary iron column conveys, the artistic sense would be satisfied by the feeling of security and delight. This plan is, I am aware, adopted in some Gothic edifices with excellent effect, but I am pleading for its more general application.

One of the uses of iron in construction, the need for which I most deeply deplore, is that of tie rods to keep together the upper walls of some churches or public buildings of any size. In the old days, when stone was the main agent in construction, and churches were built to last, the walls were sufficiently strong to stand of themselves, and not only so, but were equal to resist the storm without, and to sustain the weight of the superincumbent arch without any adventitious assistance. But now a church is built cheaply by contract, and on the conditions that it is to be as large, as convenient, and as richly decorated as may be at the smallest possible cost. The question is, therefore, how thin the walls can be made with safety. Instead of the rich mullioned windows in simple, yet sweet, stone-carved foliations at border and head of column, you have the shallow plastered arch, the weak brick divisions, the painted iron column, and simulated Gothic capital in iron casting; but, last of all, and to crown the degradation, we have the iron tie-rods across the base of the arch of the roof at intervals as you walk down the nave, and you feel that the commercial spirit has injuriously acted upon our modern ecclesiastical architecture. If congregations would consult reality rather than show, and would content themselves with more modest structures which, from foundation to roof-crest, should be thorough and lasting, the architect would have a fairer chance, and the edifice would reflect more sincerely, that thoroughness and stability of character which it is the object of religion to build up.

There is little doubt that the great development in the art of the worker in metals in the middle ages arose from the warlike necessities of the times. Not only were the weapons of warfare fashioned with the nicest regard to the services they were intended to perform, but as a man clad in a suit of armor could safely contend against many of the dangers to which he was exposed in the field, this requisite of war brought all the skill and taste of the metal-worker into constant exercise. Thus all that the craftsman could devise in the way of adaptation, and all that the artist could suggest in beauty of form or ornament of surface was brought to bear on the helmet and the coat of mail, on the sword and the firelock. An educated art-workman was thus created, and when he had done his best for the soldier, the priest was not slow in pressing him into the service of the Church. Thus we get the elaborate and beautiful locks, the door-hinges of the Cathedral, the screens, gates and rails which form so remarkable a feature of our ancient ecclesiastical edifices. It is not too much to say that this art is still among us. I hardly know a more beautiful specimen of Early English style metal work than the brass screen which has recently been executed and placed in Salisbury Cathedral by Skidmore, of Coventry. But it is unquestionably true that in proportion to the population and to the means of production of the present century, the art metal work of the middle ages was far more abundant, more correct in treatment, more delicate in expression, more elaborate and thoughtful in detail than the metal work of modern times. There is in South Kensington Museum a chair in silver repoussée, a royal chair in more senses than one. In addition to the beautiful proportion of its various parts and tender propriety of its lines, it is divided into compartments of surface by rich and suggestive ornament. Each compartment, of which there are a great number, contains a bas-relief. The bas-reliefs, all charmingly executed in repoussée, depict a genealogy, commencing with Adam and Eve in the Garden of Eden, going through a large portion of the history of the Bible, and lastly branching off into some fabulous pedigree, connecting all that preceded with the history of the country and of the king in whose reign the princely seat was fashioned. You may probably agree that there is much redundant effort, an excess of luxury, and some undue flattery in all this. It is not likely that an order for such a Chair of State would be given by any potentate in Europe to-day, nor is it desirable that there should be. Yet this is an instance, an extreme one if you will, but an instance of the great perfection to which the art of the metal-worker had attained in an age otherwise dark, and in many respects lacking the knowledge and opportunity now possessed by the civilized world. The excellence of hand and eye which had then been obtained by the worker in metals was, however, in unison with, and walked hand in-hand with the architecture of the time. The style of the Chair of State was the style of the hall of the palace in which it was a central ornament. As you entered the Cathedral and noted the exquisite tracery of the lock, you saw that it had much in common with the tracery of the windows and of the roof. Every touch of the worker in metals was, in point of fact, in harmony with the building for which his work has designed, and this consideration brings me to the central part of my subject.

It is my misfortune to pass nearly every day on my way to business a hideous mass of bricks and mortar put together on strictly commercial principles. I had said bricks and mortar, but I should have said wide columns of bricks and mortar supported on narrow square-moulded columns of cast iron, having between them successive rows of glass-covered apertures dignified with the name of windows. I must premise that in one or two of the apertures in the lower row, doors were inserted, and when I have said there is a roof, I believe I have sufficiently described a piece of utilitarianism which illustrates the full and complete avoidance of every principle of art. This may be another extreme instance, and the Chair of State of the middle ages on the one hand—the cast-iron columns of this midland erection of the year of grace 1880 may be taken as the opposite poles in metal work. It is a sad confession that the contrast is not in favor of the present day; and this directs us to the singular tendency in this respect of modern architectural progress. Now the architect, as a necessary part of his education, must be somewhat of an engineer. His knowledge of iron must be important and varied. He must understand the supporting power of an iron column as compared with that of stone, brick, wood or other material. He must gauge the relative capacities of endurance and resistance of iron, and its cost in each case as compared with other means of construction. The utilitarian element must be studied carefully by him, and every new principle or mode of metal construction economically applied, or he will be in danger of being passed in the race for success by men perhaps otherwise of far less capacity. All this the modern architect must do, all this he will do, in spite of the denunciations of art-critics. Though Mr. Ruskin may inveigh against this feature of the iron age, and though we may own with regret the justice of many of his positions upon this subject, yet all this will not advance the question much. The architect is, after all, like every other professional man, the servant of the public, and though he may within certain limits guide and help the public in the way of taste, yet the public will always determine for him that very important question, the limit of expenditure upon a given building. And if the public is keen upon any points affecting the architect, it is upon the economical construction of a building. To obtain the best accommodation for the lowest price, to have as little wasted space as possible, to carry the greatest weight at the smallest cost, and to have as much light and as much window frontage as the land will allow; these are the needs of many clients, who, though ignorant or careless of all else, must be satisfied upon these points. The architect must meet these demands. He is helpless to refuse the conditions offered him, because if one architect does so refuse, there are a dozen others who will gladly comply with them. What, then, can he do? In the answer to this question lies, I conceive, the measure of the influence which the architect is able to exert upon his time.

I have said that the architect may, within certain limits, guide and help the public in the way of taste. He can do so in the first instance, by complying with the demands of the public, but, nevertheless, in all his work giving a bearing in the direction of true art.

When Haydon, the painter, set up his theory, no doubt a correct one, that a great historical art was altogether wanting in this country, and then, in pursuance of his theory, set to work painting such pictures of proportions to which no buyers could be induced to respond, we know that he made a serious, a fatal mistake. But when the late E. M. Ward, R.A. (whose end, alas! was equally sad, though probably from very different causes), painted historical pictures with a finish and of a size suited to the dainty dining-rooms or galleries of the British merchant and manufacturer, his success was at once assured. The lesson should not be lost upon the British architect. Without a Quixotic tilting at all the windmills of phantasy which a non-professional critic can fairly indulge in, the designer of a public or private building, if he has the correct aim in view, and if he has a genuine love of his art, can carry out the wish of his patron or client, yet always with a determination to make the edifice better, truer and purer in style than his uninformed proprietor could have expected.

The old Italian conception of the architect was that he was a "Grande Maestro," a complete supervisor as well as designer of a building, and thus that he must have complete control of the construction from beginning to end. In the days when artists like Leonardo da Vinci and Michel Angelo were architects, this title was no empty name, and while the outlines of a building were traced by their decisive pencils, many of the details, and notably more of the decorations, were finished by their own hands. It is not, of course, to be expected that this could be the case in these modern days. The complexity of life is so vast and intricate, the division of labor is so complete, that a man can only attempt to know and understand one thing well. But the one thing that the architect should know well is the way in which the conception or idea of a building should be carried out even to its veriest details. If the architect realizes the spirit of his calling, he should not be satisfied when he has supervised the erection of the mere shell of a building. If he leaves the decoration of the interior to others, who can say but that the mere decorator will lose altogether the essential beauty of the style in a crowd of inharmonious details? I may say, in passing, that I consider the effect of the new Council Chamber in Birmingham is seriously injured from this very cause. If, again, the architect leaves the decision as to all the minor ornamental metal-work to others, the same result will probably ensue. This will be the more unfortunate, as with the necessity now existing for plain, simple, economical construction, the only special opportunities the architect has after the general form and proportion of the front elevation has been decided, consist in the ornamental metal-work, and small decorative features. The grill ornament upon the summit of the roof-line, the spouting, ridges, locks, hinges, palisades, and gates are often the only saving clauses he can be allowed to expend his taste and knowledge of style upon, after the huge block of commercial buildings has given its additional mass of shadow to the crowded thoroughfare. Here, therefore, at least, art may blossom, and if the architect is indeed the "grande maestro" he will not be satisfied until some at least of the plainness and simplicity of the modern fabric is warmed into beauty by the sympathetic touches of his ornamental metal work. What is thus too often left to chance or caprice will become to him an important vehicle for conveying that sentiment of taste and fitness which every true architect will desire to reflect in his work. Gutters and spouting, which are now either concealed or left in their naked ugliness of line, as necessary blots upon the building, or as nuisances that cannot otherwise be got rid of, would be turned to true artistic purpose, and made to assist and beautify the effect of the edifice to which they are attached. In the same way, the manufacture of locks and hinges, instead of having become mere specimens of mechanical utility, holding their own with resolute economy of construction against American competition, might again become a fine art. There is no room to doubt that if the modern architect turned his attention earnestly to this subject, we might have the great art-period of the lockmaker of the middle ages restored.

In saying this, I do not mean to infer that such art does not exist now. I believe it does exist, and we have all evidence indeed that when any specially beautiful work of this character is required, and when a heavy price can be paid for it, such work, equal, nay perhaps superior in some respects, to the fine metal-work of the middle ages can be produced. But these are essentially products of luxury, so much out of proportion to the relative cost of such examples in past times, and so much beyond the economical needs of ordinary building construction, that they can hardly be expected to become general. The difference between these old metal-workers and the present is that the former had a real pride in and love for his art, that he worked on true principles with some knowledge and taste, and that whether by his own sense of fitness, or by the design of the architect we cannot now always determine, but by some cause or other his productions always harmonized with the buildings to which they were attached, and assisted in the unity of the leading idea of the style. This appears to have been the rule with the ordinary metal-worker of the middle ages; with us moderns it is the exception. We know there are men, and great art-manufacturers who fully answer to this descrip tion; but what of the mass of workmen? Are they not a reckless crowd of Cyclops kind, with one eye only to their work, and that fixed upon it with a view only as to what wages it will bring? The mere mechanical requirements which have been deemed essential have been satisfied in this manufacture, and as little else is asked for by public or by architect, nothing else is given. But there is every reason to believe that, if the professional educated class who are expected to guide the taste of the public in the matter of building construction in Great Britain—if this class will only rise to the occasion and assert its right to superintend and improve these details—a great change will take place. The needs of art-education, both for masters and workmen, are now fully recognized, and though many blunders are being made in the steps taken to remedy this state of things, all these efforts are in favor of the architect, who knows what he wants, and who desires to have metal work to harmonize with his designs. A general demand for art in architectural metal-work will certainly, in time, bring about an adequate supply. What is more—an educated metal-worker will in a certain period be built up, and those beautiful specimens of art-work, which are now the luxuries of private palaces or public buildings, will become the natural and frequent adornments of even ordinary streets. What is now so costly will be brought within reasonable limits of price, not because the workman is reduced to wages just above starvation level, but because his educated hand and eye enable the average artisan to execute with pleasure and profit what he now cannot conceive or execute at all. This is, to my mind, one of the most important considerations which should weigh with the architect in taking the subject up, and it is one which should encourage him to persevere in asserting his right and privilege, to make the metal-work of his buildings the delicate finishing touches which shall emphasize and vitalize the principle of design he has embodied.

It is a good feature of the Bethnal green Museum that the authorities of South Kensington have gathered together a large number of specimens of architectural metal-work, and have arranged them so that they can be there studied with advantage. The next thing which is desirable is that every great manufacture center for metal-work should have its branch exhibition, either supported by important loans from South Kensington, or, still better, by grants of specimens of the kind specially suited to the trades of the locality. The first principles of fitness of style will then be learned by the ordinary worker in metals; and then, if the architect keeps the important end in view, the true idea and practice of finish will follow. The malleability, the pliability of metal, the exquisite delicacy to which it can be wrought, all adapt it to the purpose of the architect who desires to relieve the heavy masses of his edifice with the tenderest touches of beauty. Mr. Ruskin, in one of his books (I forget which, for the moment), describes a front of Italian verandah, in hammered iron, in the center of which a bouquet of flowers was wrought with such grace and sweetness that he avers he has seen nothing comparable to it in modern work. The old gates of Hampton Court, designed and wrought in the 17th century by Shaw, of Nottingham, and now a portion of them at Bethnal-Green Museum, are studies in the much-discussed style of Queen Anne.

THE THEORY AND CONSTRUCTION OF THE LEADING FORMS OF ELECTRO-MOTORS, AND THEIR EMPLOYMENT IN THE PRODUCTION OF THE ELECTRIC LIGHT.*

By Prof. HENRY MORTON, Member of the Light-House Board.

In whatever way electricity is to be used as a source of light, there is, of course, no question that a cheap supply must be found in order that it may compete with other means of illumination. As long as the galvanic battery was the only instrument for producing electricity, we were met at the very start by the following state of facts:

The source of energy in the battery is practically the zinc consumed. Weight for weight, coal has almost six times the available energy of zinc; while, moreover, the price of zinc is about 25 times that of coal. In the race between the two, therefore, zinc starts with this enormous disadvantage, that an equal amount of energy obtained from it will cost about 150 times as much as if obtained from coal. To make gas from coal and burn it for light will then be cheaper than to obtain electricity from zinc and turn it into light, unless the loss in the former case is 150 times greater than in the latter. Batteries, therefore, as sources of electric force for lighting purposes, are out of the question from an economic standpoint.

The possibility of economic lighting by electricity came first to exist when, in 1831, Faraday discovered that the motion of a magnet in relation to a conductor would develop a current of electricity in the latter, and thus that electricity might be developed by the expenditure of mere mechanical energy.

The first principle involved in this subject is this:

Magnets exert forces in all directions around them, but in such a way that they may be said to be surrounded by "fields of force," in which the forces are distributed in certain directions, known as "lines of force." Some notion of these is obtained if we place a plate of glass over a magnet and then sprinkle iron filings on the former, when on tapping the glass the filings will arrange themselves in certain lines.

A very beautiful method of arranging and permanently fixing such lines has been devised by Prof. A. M. Mayer, and from plates so arranged by him, Figs. 1, 2, 3 and 4 have been produced by a process of photographic engraving.

Fig. 1 shows these lines of force as they are arranged about a single straight bar magnet with its north pole at one end and its south pole at the other.

Fig. 2 shows the arrangement of these lines of force when two bar-magnets are placed side by side, the opposite poles being adjacent. In this case the lines of force run across between the ends of the bars, making a very intense magnetic field at these places.

Fig. 3 shows the arrangement of the magnetic curves about a pair of bar-magnets placed parallel to each other with their like poles together. Here the lines of force do not run across between them but are bent around parallel to the length of the bars.

Fig. 4 shows the lines of force about one end of a magnet bar and a small piece of soft iron in front of it magnetized by induction from the large magnet.

It was discovered by Faraday, in effect, that whenever a conductor was so moved in the vicinity of a magnet as to pass through or "cut" these lines of force, a current was developed in the conductor. The greatest effect was obtained when the lines were cut at right angles, and when the greatest number of lines are cut in the same time, either by passing through a denser "field of force," as near the poles of the magnet, or by moving more rapidly. When the conductor moved *along* the lines of force no current was produced.

As the conductor passed into and through the "field" of one pole a current was developed in one direction, and as it passed out of the same field into and through the field of the other pole a current in the opposite direction was devel-

* Abstract from "Reports on the Topophone and the Electric Light," by Prof. Henry Morton, Member of the Light-House Board.

oped. Between the two fields there would, of course, be a neutral point where no current is developed. Indeed, if we turn to Fig. 2 we will see that a conductor, while passing the center of the magnet, would be moving along the lines of force, and ought, therefore, to develope no current, while near the poles it

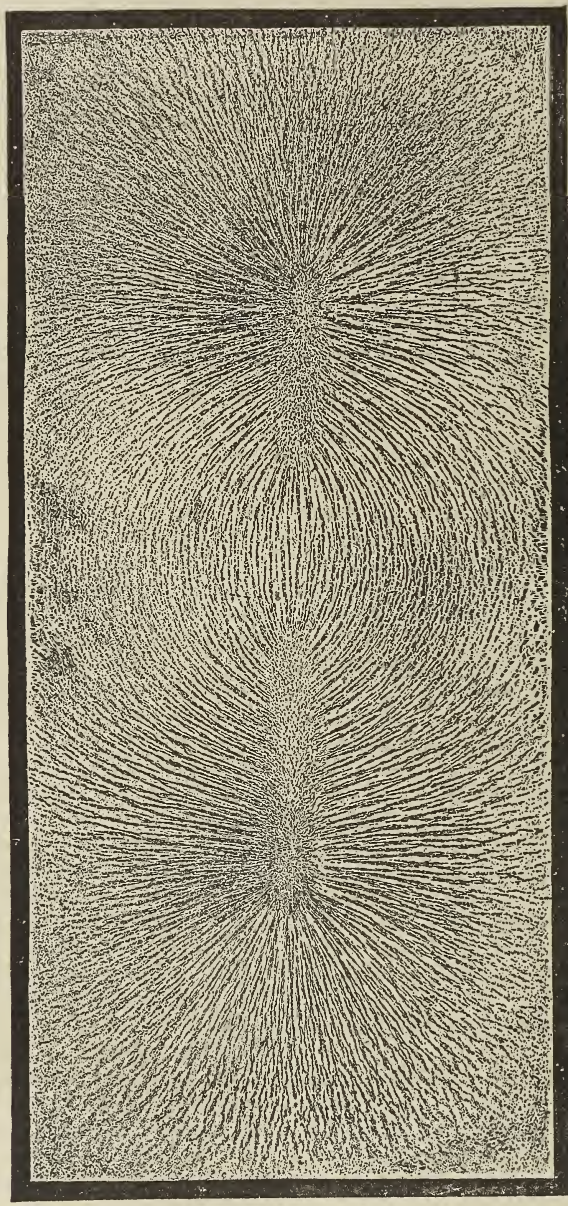


Fig. 1.

would pass at right angles to the lines of force, and so give a maximum current. At other parts of its path the conductor develops currents of more or less intensity, according as it finds the lines of force more or less oblique to its path.

While the above basis of explanation is very commonly employed in connection with our present subject, there is also another which I shall now proceed to state.

In the first place, it will be desirable to indicate the relations between magnets and electric currents first pointed out by Ampère.

According to this theory, a magnet owes its characteristic properties to the presence in the molecules of electric currents all circulating in the same direction.

In other words, if Fig. 5 is supposed to represent a short magnetic bar with its

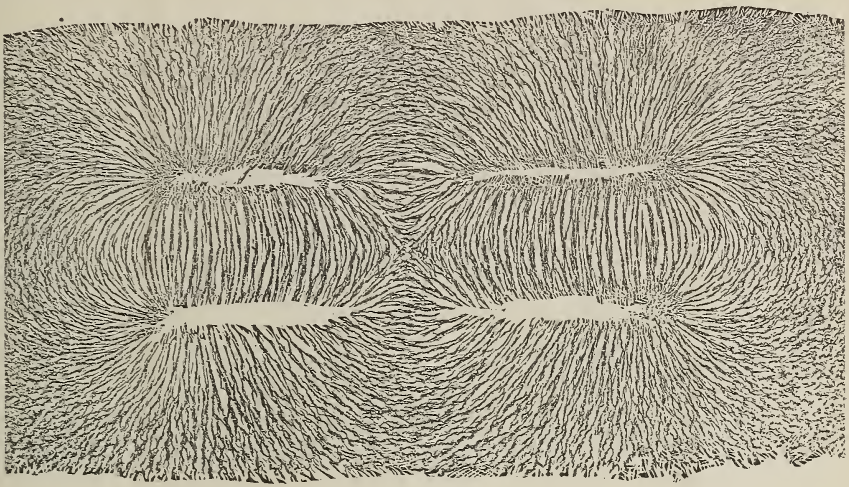


Fig. 2.

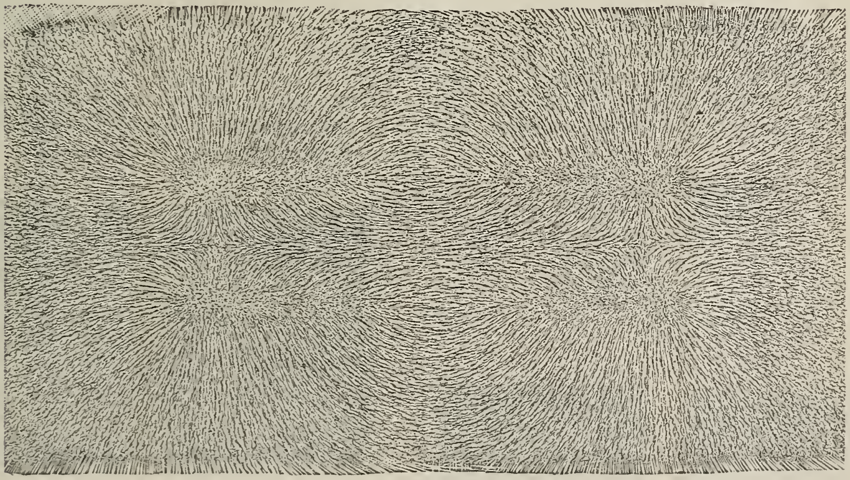


Fig. 3.

south end towards us, the little arrows would represent the direction in which the currents of positive electricity were flowing in its molecules.

The general effect of such currents could evidently be expressed by single currents passing in the entire bar, as indicated in Fig. 6, and the practical effect of such a series of parallel currents would very evidently coincide with that of a current passing through a helix, as indicated in Fig. 7.

As a matter of fact, we find that a helix of wire, through which an electric current is flowing, will exhibit all the properties characteristic of a magnet. Thus, it will attract iron, if freely suspended, point north and south, and if two of such helices are brought together their like ends will repel and their unlike ends attract each other.

This attraction and repulsion, moreover, appears to come under a still wider law, for it may be readily shown that any parallel electric currents, if going the same way attract, and if going opposite ways repel.

Fig. 8 shows how this explains the attraction of unlike and repulsion of like poles in magnets.

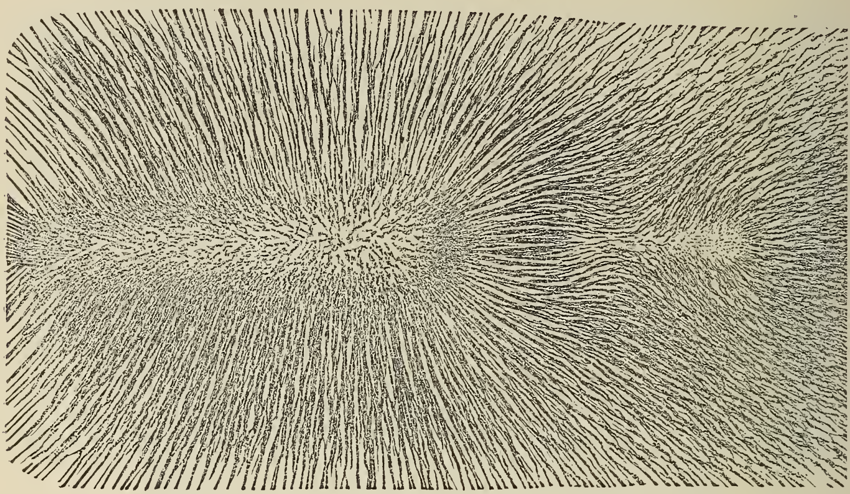


Fig. 4.

In A and B, the north and south poles being opposite, the magnetic or electric currents flow parallel and in the same direction, and thus attract, in A′ and B′, the two north poles being together, the

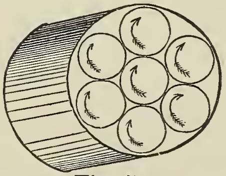


Fig. 5.

Fig. 6.

Fig. 7.

currents flow in opposite directions, and thus repel.

Another general law must next be stated, namely: Whenever a conductor approaches a parallel current, a momentary flow of electricity is established in the said conductor, opposite in direction to that of the current towards which it is moving; as the same conductor recedes from the current a momentary flow in an opposite direction is produced.

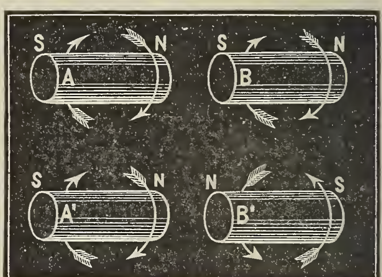


Fig. 8.

Let us see how this applies in such a case as we have now to consider.

Let N S, Fig. 9, represent a magnet in which the magnetic currents are flowing as indicated by the arrows on the bar; if, then, we bring a conductor, like the loop of wire to the right, towards the south end of this magnet, a current will be developed in the loop opposite to the currents in the magnet, because the loop is approaching all of them. If now the loop continues to be moved forward over the S end of the magnet, when it comes over, say, the point *n*, it will still be approaching many of the magnetic currents, but will be receding from a few, those namely, which it has already passed. There will, therefore, be an interference between the opposite currents due to the approach to the magnetic currents to the left, and the recession from those to the right, and the resulting current will, therefore, be feeble, although still in the first direction.

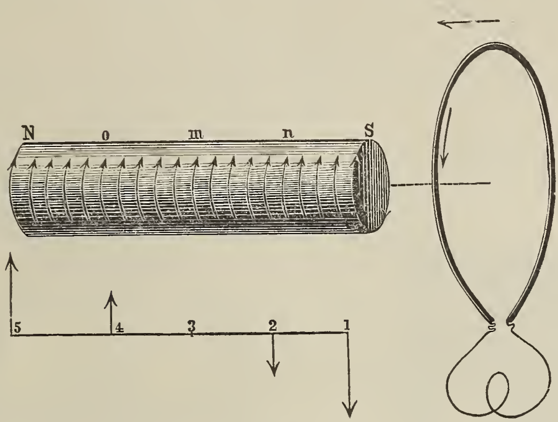


Fig. 9.

When, however, the loop comes over *m*, the number of magnetic currents it is leaving is just equal to that of those it is approaching, and the two currents will, therefore, be exactly neutralized.

Beyond *m*, towards N, however, the current due to the withdrawal from the magnetic currents will predominate and increase until the north end of the magnet is passed.

The horizontal lines with vertical arrows, at the lower part of Fig. 9, represent the directions and relative intensities of the currents developed as the loop moves over the magnet from right to left.

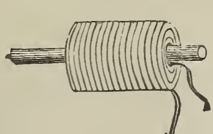


Fig. 10.

It will be readily understood that it is quite immaterial whether the conductor is moved over the magnet or the magnet is moved through the conductor.

Thus, if the conductor is wound into a coil, as in Fig. 10, and the magnet is pushed into or drawn out of it, we shall have a like production of currents.

Or again, if the coil should have in its center a bar of soft iron, and this should be magnetized by the approach of a magnet, and then lose its magnetism on the withdrawal of the same, this will be equivalent in effect to the sudden insertion and withdrawal of a magnet.

The first attempt which was made to utilize the above-described principles in producing a current of electricity from a magnet by the expenditure of mechanical energy was that by Pixii, of Paris, who, in 1832, produced the apparatus shown in Fig. 11.

Here two coils of wire, with soft iron cores, are supported at the upper part of a frame, while below them a strong steel magnet is made to rotate by appropriate machinery. As each pole of the magnet in turn comes opposite the iron core of either coil, it renders it instantly magnetic, and thus develops a current in the surrounding coil. These currents, of course, are alternately in opposite directions, and to correct this a "commutator" is placed below on the moving shaft, which, by reversing the connections at the right moment, sends the currents always in the same direction through the exterior wire.

Saxton, in Philadelphia, made, in 1833, a modified form in which the steel magnets were placed horizontally, and remained at rest, while the coils with their soft iron cores were rotated opposite their ends. Various small modifications followed. Thus, in 1836, Clarke, in London, made a machine represented in Fig. 12, in which the steel magnet was made of several single magnets united, and the coils were rotated opposite the poles, but at right angles with the plane of the magnets.

Again, Breton wound coils on the poles of the magnet, and then rotated an armature in front. This armature, by its approach and withdrawal, caused movements in the lines of force, or in the magnetic currents, which developed momentary currents of electricity in the coils of wire. The relation of this action to Brequet's apparatus for exploding mines, and to the Bell telephone, is worthy of notice.

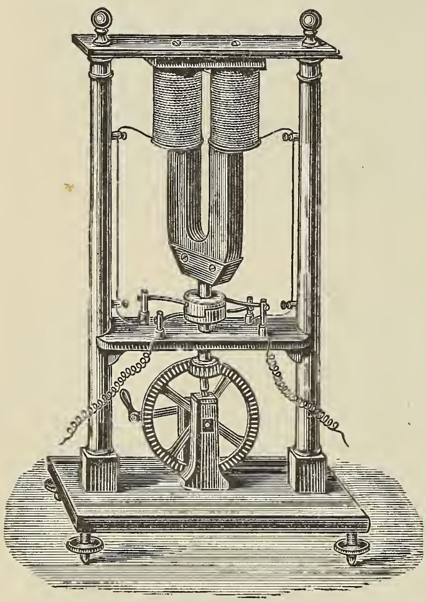


Fig. 11.

Duchenne combined this last plan with the preceding one by winding coils both on the magnet and the armature, and using one or other of the circuits for his induced current.

The first attempt to make a magneto-electric machine of such a size as to be available for industrial purposes, was made in 1849, by M. Nollet, professor of physics at the Military School at Brussels.

The original intention of those first engaged in developing this machine was not, however, to produce with it an electric light, but to employ it to *decompose water in order that the hydrogen so liberated might be used as an agent of illumination.* If we were in want of an illustration of the extravagance and irrationality of expectation which so often exhibits itself in enterprises entering upon new fields, we surely need go no further than this. M. Nollet died before his designs were entirely carried out; but they were elaborated by an intelligent workman who had assisted him in the construction of his machines, M. Joseph Van Malderen, who, under the auspices of a company composed of French and English capitalists, and named the "Alliance Company," developed the apparatus into an efficient generator of electric currents for the direct production of light by means of the electric arc.

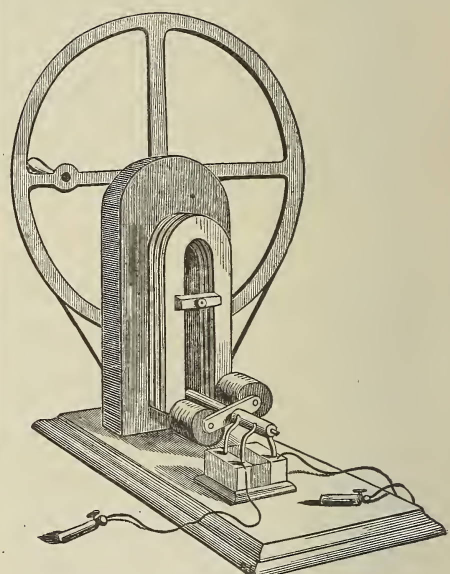


Fig. 12.

The apparatus, as thus constructed, was, in general principle, only an enlargement of the Clarke machine, and consisted of a large number of compound steel magnets, between the adjacent sides of which cores of soft iron, surrounded with coils of isolated wires, were made to revolve. An appropriate connection of these various coils with each other, and with commutators on the axis, enables the current to be taken off in a constant direction. When it was afterwards discovered that, for an electric light, the current need not be constant in direction, but was even more convenient when rapidly alternating, this was of course yet more easily provided for. Fig. 13 shows one of these Alliance machines, which really needs no further description, its structure and operation being rendered perfectly clear by the cut.

Many of these "Alliance machines' were made and used in different places

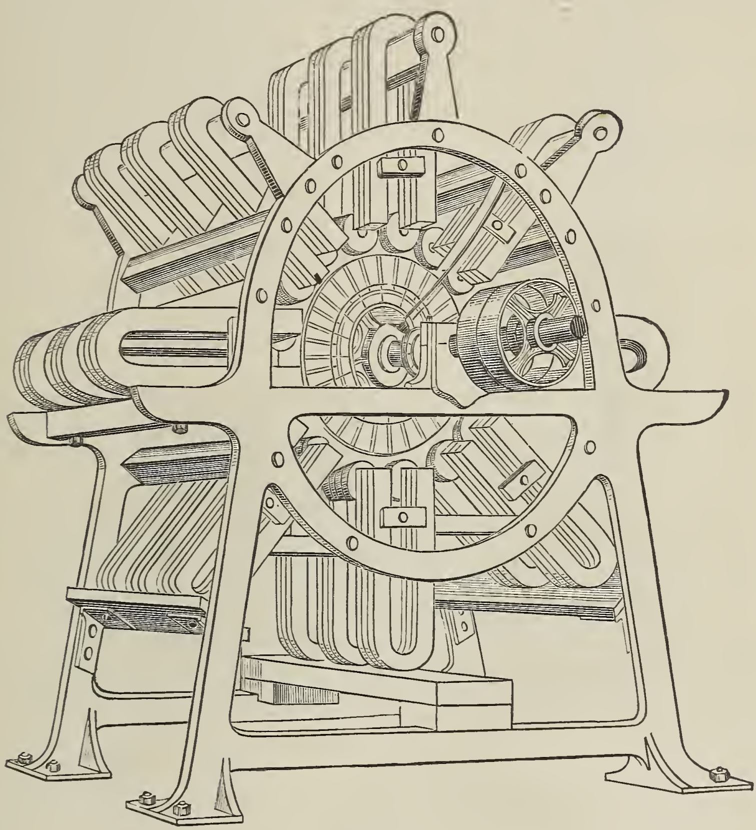


Fig. 13.

in France for lighting works of construction at night, such as the Cherbourg docks, and on some vessels, as the Lafayette and the Jerome Napoleon, and in some light houses; and, as modified slightly in arrangement of parts by Mr. Holmes, in England, notably in the South Foreland light house.

The great cost of these machines, the large amount of power required to run them, and the cost and trouble of keeping them in repair, however, limited their use to a very narrow field, and they could hardly be said to have carried the subject of electric lighting beyond the range of an interesting scientific experiment on a large scale.

The next important step in the development of the magneto-electric machine consists in the application by Dr. Siemens, of his peculiar armature to these instruments.

This armature is shown in longitudinal section in Fig. 14, at E, and in cross section at F.

The armature is in fact a rod or bar of soft iron, with deep grooves cut lengthwise along it, reducing its section to an

H form, as is shown in F. Insulated wire is then wound lengthwise in these grooves, as shown in E. Such an armature as this, mounted with caps, as shown in Fig. 14, may then be rotated in a very narrow and dense magnetic field, and its wires will cut many lines of magnetic force in a short time by reason of their rapidity of angular movement, being close to the axis of rotation.

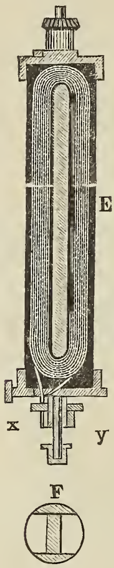


Fig. 14.

This armature was first used in magneto-electric machines employed for telegraphing by Siemens in 1857.

The next advance, and this a very marked one, was made in 1866, by H. Wilde, of Manchester, who, on April 13, communicated to the Royal Society the result of a series of experiments with magneto-electric machines, of which Fig. 15 is a good representative.

In this machine a number of small horseshoe magnets are so arranged that a Siemens armature may be rotated between their poles.

The coils on this armature have developed in them, by moving in this highly concentrated magnetic field, a very powerful current. This current is then passed through heavy coils of wire surrounding the sides of a large U magnet, made of massive plates of wrought iron. Between the poles of this rotates another Siemens armature of larger size, from which a current of immense power is obtained.

While the electric current developed by this machine far exceeded anything

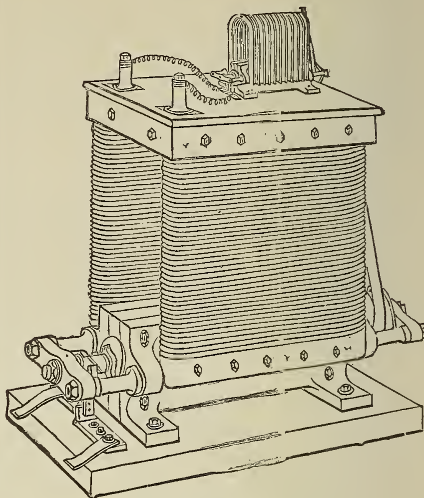


Fig. 15.

which had ever been obtained before, it was only secured by a large expenditure of power—something between a five and

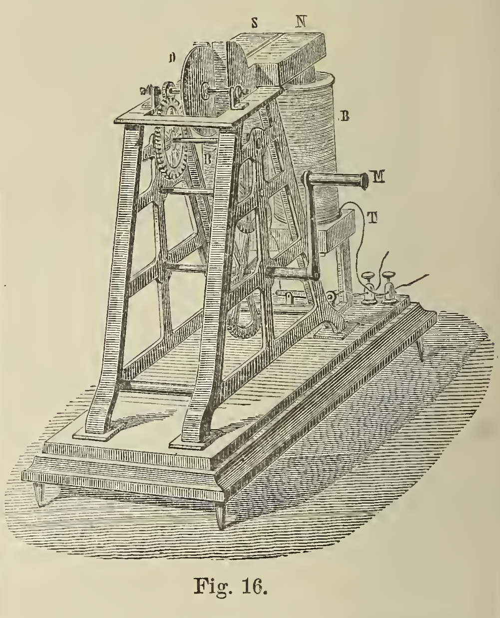


Fig. 16.

a twenty horse-power engine being required to drive it.

The important fact developed by Mr. Wilde in this machine was that a magneto-electric machine could develop a current whose magnetizing power was vastly greater than that of the magnets from which it was derived. Thus, if the small magnets above would lift a weight of 50 pounds, the large electro-magnet below, when excited through their instrumentality, would lift 500 pounds or more. This possibility of a sort of magnetic accumulation of growth was a demonstration of immense value to the progress of magneto-electric science.

A practical difficulty which first showed itself in a conspicuous degree in these very powerful machines was the heating of the armature. Foucault had first shown, long before, that when a conductor was rotated or moved in a magnetic field it became strongly heated.

His apparatus to illustrate this is shown in Fig. 16, where a copper disc is rotated between the poles of a powerful magnet, and becomes very hot.

Tyndall, by similarly rotating a copper tube, melted the fusible metal with which it had been filled.

The heat developed in the armatures of Wilde's large machine was so great as to cause serious inconvenience, and of course involved a great loss of effect or waste of power.

In 1867 Siemens proposed a very obvious modification of this machine of

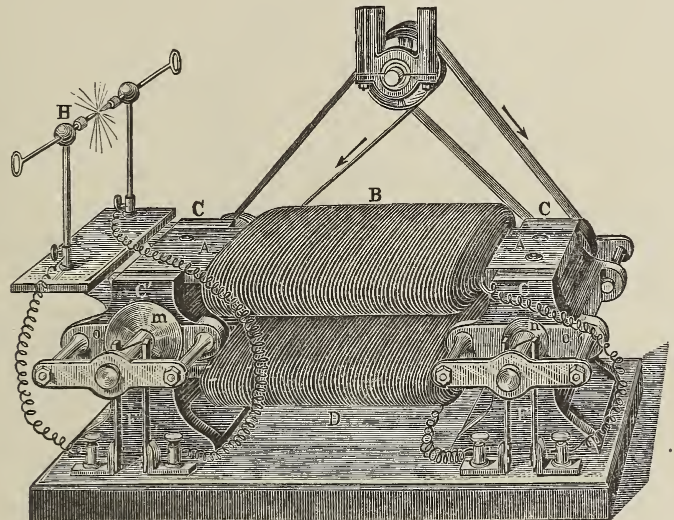


Fig. 17.

Wilde, by dispensing with the smaller machine and connecting the coils of the large one with its own armature through the commutator of the same. The residual magnetism of the iron of the electro-magnet was found sufficient to start the action, which then increased by self-development.

This, however, occasioned what was at first regarded as a serious difficulty.

If the magnetism of the electro-magnet was thus made to depend on the current of the machine itself, any interruption in the flow of the same in the exterior circuit at once cut down or destroyed this magnetism, and so reduced the whole action.

To obviate this, Ladd, of London, first made a machine with an armature wound with two coils of wire, one being connected with the magnet of the machine, and the other with the exterior circuit.

Afterward he made a machine in the form shown in Fig. 17, where two armatures were used—one connected with the coils of the machine itself, and thus supplying what is often called the "field of force," the other supplying the exterior circuit.

Subsequent experiment has, however, shown that the arrangement is very far from economical in the conversion of energy, and all the machines now in use include the exterior circuit and the field of force in one continuous connection.

This, of course, greatly complicates

the relations, and makes the fluctuations during running greater and more numerous; but for the sake of efficiency or the economy of expended power, it has been found essential to adopt this arrangement.

PACINOTTI'S RING MACHINE.

The first magneto-electric machine for the production of an electric current continuous in character and constant in direction and intensity was that devised by Dr. Antonio Pacinotti in 1860, and constructed by him for the physical and technological cabinet of the University of Pisa. A description of it, however, did not appear till several years later, in the June, 1864, number of the Italian scientific periodical, "Il Nuovo Cimento." This number, which was published during the month of March, 1865, contained an extended illustrated description of the machine.

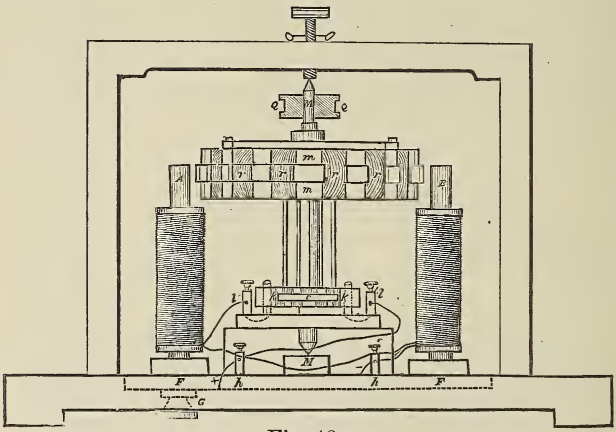


Fig. 18.

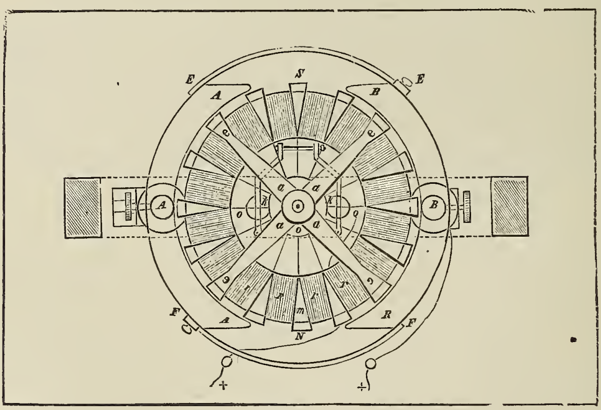


Fig. 19.

As a special feature of the apparatus he pointed out the peculiar form of the movable electro-magnet—a circular iron ring in which, contrary to the case with the armatures previously in use, the magnetic poles did not remain stationary, but could be moved within the ring—that is, made to assume in it successively all possible different positions.

This movable ring of iron had the shape of a spur-wheel of 16 teeth, and was firmly secured to the axis of the machine by means of four strips of brass. Small wooden wedges were placed upon the teeth of the ring, and the space so formed between each two of the wedges filled up regularly with insulated copper wire. These spools were all wound in the same direction, and the terminal end of each was soldered to the beginning of the one succeeding it, so that the whole system of 16 spools virtually formed a single coil of wire surrounding the ring in a regular manner, and returning upon itself.

Wires were soldered to the separate points of juncture and were led, parallel to the axis of rotation, to an equal number of insulated pieces of brass, mounted in two rows upon, and slightly projecting from, the surface of a disk firmly secured to the axis.

The iron ring, with the bobbins wound upon it in the manner already described, was mounted in a horizontal position between the two legs of a powerful upright electro-magnet, the distance of which from the ring could be adjusted at pleasure by means of a set-screw and a slot in the lower connecting cross piece. Contact rollers *k k* were made to press, one on each side of the axis, against the lower wooden disk carrying the strips of brass, so that during the rotation of the ring all of the latter were brought successively into contact with them. When, there fore, the terminal posts *h h'* are placed in connection with the poles of a galvanic battery the current will pass, supposing it to enter at *h* (+), by way of the binding-post *l* to the roller *k*, and through the strip of brass on the disc against which the roller may happen to press at the time, up to the two wire coils of the armature whose point of juncture is in connection with the strip of brass.

The current here divides, each portion passing in an opposite direction through the spools surrounding each half circumference of the ring, to meet again to form one current at the left contact roller *k*, whence the reunited current passes to the second binding-post *l'*. From here the current proceeds to the leg A of the electro-magnet, circulates around it, and, after acting similarly with regard to the other leg, B, passes back by way of the binding-post *h'* to the negative pole of the battery. Magnetic poles thus became developed in the iron ring at the points N S, the position of the contact rollers having been so chosen as to bring about this effect, and the actions of attraction and repulsion taking place between them and the poles of the stationary electro-magnet, gave rise to the rotation of the ring.

In order to turn the action of the electro-magnet upon the magnetized iron ring to the greatest possible account, Pacinotti provided the two poles with armatures, A A A, B B B, of soft iron, which were made to surround the ring very closely for over two-thirds of its circumference. Strips of brass, E E, F F, attached, served to give them greater security. In the elevation of the machine here given these armatures have been omitted in order not to conceal the ring and its surrounding spools.

The foregoing description of the ring of Pacinotti and its action has more especial reference to its application in an electro-magnetic machine, but toward the end of his article Pacinotti clearly indicates in what way, by the use of the same annular armature, the electro-magnetic may be converted into a magneto-electric machine, capable of producing, by the proper use in connection with it of a permanent or electro-magnet, a continuous current of a constant direction.

On substituting for the electro magnet A B a permanent magnet, and on rotating the ring armature, the poles induced in the ring by the proximity of the magnet will always be found at the extremtieis of the diameter passing, when produced, through the poles of this exterior magnet; so that we may come to consider the spools as alone partaking of the rotary motion, while the two semicircular magnets produced by the induction remain at rest. The current induced in any particular spool will, in the motion of the latter from N to S, preserve the direction it has on leaving N until it reaches *a*, a point midway between N and S. Here a reversal in direction of the current takes place, which new direction is preserved until the spool arrives at *b*, a point midway between S and N, where a reversal to its former direction of the current occurs, and so the action continues. The current developed in the different spools will therefore add to each other's effect, and are hence most properly collected at the points A and B, the collecting brushes coming thus to act upon the commutator at right sngles to the magnetic axis of the rotating arma ture.

Pacinotti did actually obtain an uninterrupted current of constant direction on causing the opposite poles of permanent magnets to approach the ring during the rotation of the latter. He also obtained the same effect by magnetizing the stationary electro-magnet by means of a current, though he deemed the former method preferable.

We have already drawn attention to the peculiar form of armature devised by Dr. Werner Siemens and used by Wilde in his magneto-electric machine in 1866.

A similar armature, as used by Siemens himself, in one of his earlier machines, is shown in Fig. 20.

This is, strictly speaking, a *magneto-electric* machine, as the field of force in which the armature revolves is produced by the *permanent* magnets, of a V form,

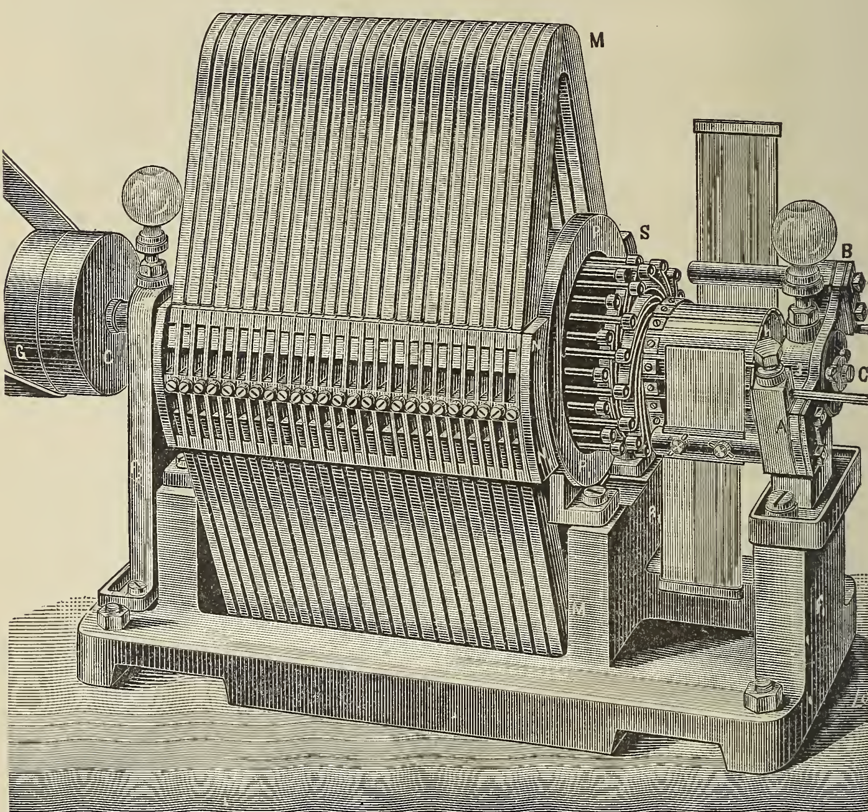


Fig. 20.

which constitute such a conspicuous feature of the machine.

Dr. Siemens was among the first, if not the first, to introduce in his machines the reciprocatory principle of passing the current from the armature coil around electro-magnets by which the field of force was developed, and his large dynamo-electric machine so arranged is shown in Figs. 21 and 22.

We can give no better description of this machine than that contained in Dr. H. Schellen's recent work, "Die Magnet und Dynamo-elektrischen Machinen," and I therefore simply translate as follows:

"We have already drawn attention to the fact that when metallic bodies are caused to move in a magnetic field, such motion develops in them induced, or so-called Foucault currents, which, if not conducted away, become transformed into heat, and thus, according to the circumstances of the case, give rise to a considerable heating of the metallic bodies in motion. As long, therefore, as the iron core revolves with the coiled drum through the magnetic field of the exterior magnets, in the magneto-electric machine just described, these currents are not to be avoided, though they may be diminished to some extent by constructing the armature of coils of iron wire instead of massive iron. In such machines, however, which are built for the purpose of producing very large quantities of electricity, and which for this reason are constructed in accordance with the dynamo electric principle, these Foucault currents would be attended by a considerable increase in the temperature of the machine, in addition to which considerable power would be required in

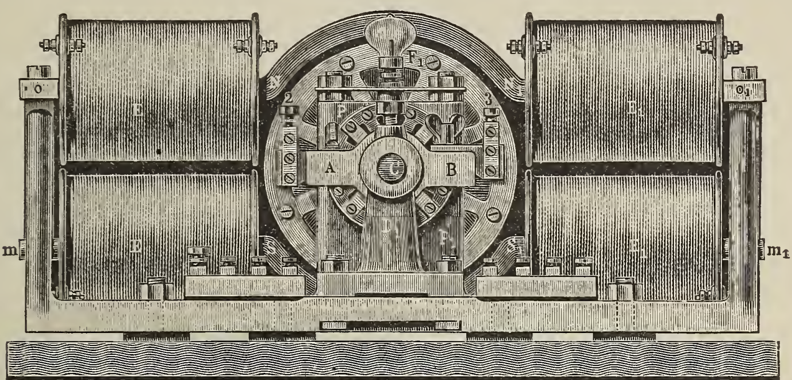


Fig. 21.

order to rotate the iron armature, owing to its becoming so strongly polarized by the powerful electro-magnets developed, for which power there would be no equivalent return in useful effect.

"These considerations must have determined the inventor to secure the iron armature inside the drum, and so prevent it from taking part in the motion of the latter in such dynamo-electric machines, like those to be used for illuminating purposes, for instance, as are intended for the production of large quantities of electricity. As a matter of course, this renders the construction and mode of arrangement of the drum much more complicated, and all the more so when it is considered that the long drum, with its surrounding coils of wire, has to be moved through the narrowest possi-

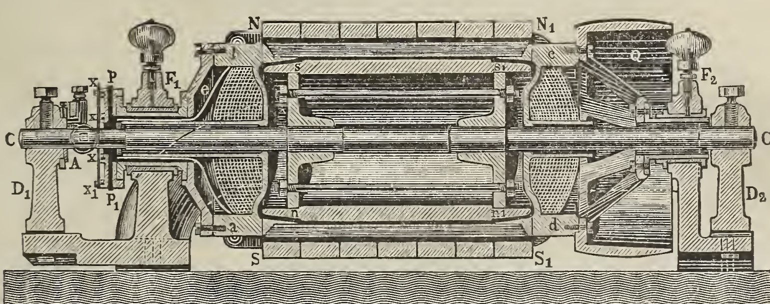


Fig. 22.

ble space between the pole armatures of the electro-magnets and the stationary inner core.

"Figs. 21 and 22 represent the construction, in detail, of such a dynamo-electric machine on the v. Hefner-Alteneck system. A horizontal section of the drum and a side view of the complete machine are there given. *a b c d* is a thin German silver drum upon which, in the manner already described, the wire is wound in many circumvolutions, and in eight separate coils. Each terminal face carries a short tube, which tubes form the trunnions of the drum, and lie in boxes, F_1 and F_2, provided with oil-cups.

An iron shaft, C C, secured by means of screws in the pillars D_1 and D_2, passes through these tubes into the interior of the drum, where the core $n\ n_1\ s\ s_1$, held together by two disks bolted to each other, is fastened upon it. The drum is surrounded on the outside at two opposite places for about two-thirds of its circumference, and over its entire length, by two curved iron armatures, N N_1 and S S_1. These are placed as closely as possible to the wire drum, and form, with the stationary hollow interior core, $n\ n_1$, $s\ s_1$, a narrow annular space, the magnetic field, through which the drum *a b c d*, with its surrouuding wires, must be able to pass in its rotation with all possible freedom.

"Inside of the front hollow trunnion of the drum which rests in F, there passes another hollow tube, which is secured to the end face of the drum, and between which and the trunnion the ends *ee*, of the separate wire coils, are led through to the commutator, $p\ p_1$, attached to its front end.

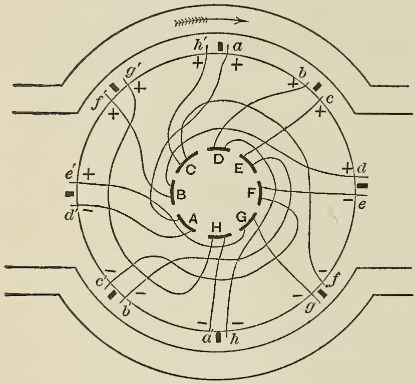


Fig. 23.

"The two curved iron armatures, N N, and S S, terminate in flat plates, N *o* S *m*, and $N_1\ o_1$, $S_1\ m_1$, which constitute the cores of the electro-magnets EE, E_1 E_1, and through which the armatures are rendered magnetic. These cores are united at their ends by strong soft iron connecting pieces *o m* and $o_1\ m_1$, which also serve the other purpose of forming the side portions of the cast-iron frame work of the machine. Here also the wires of the two horseshoe-shaped electro-magnets, E and E_1, are wound in such a way that the poles of the same name are opposite each other, so that all portions of the iron arch uniting each set of these poles exhibit the same kind of polarity. In this way the drum and the interior iron core are surrounded for about two-thirds of their circumference, and over their entire length, by the stationary exterior magnetic poles N_1 N_1 and SS, and a very extended magnetic field formed by this means, the intensity of which will be the greater the more powerful the induced currents developed, and, in consequence, the poles of the electro-magnets, become.

"In order to carry out the dynamo-electric principle, the coils of the two electro-magnets E E and E_1 E_1, are connected with the commutator brushes, or the contact rollers, in such a way that the current generated by the machine traverses successively the wire surrounding the drum, the coils of the electro-magnets, and the electric lamps placed in the circuit. The two systems, the induced currents of the drum and the poles of the electro-magnets, exert, up to a certain maximum limit, a mutual strengthening action upon each other, which limit is determined by the wires upon the drum, the velocity of rotation of the latter, and the mass of iron in the cores of the electro-magnets."

Connections of ends of coils of armature cylinder in the Siemens machine.—The attachment of the ends of the coils to the sectors is represented in the accompanying diagram, which shows an armature of only eight coils, there being the same number of commutator plates. The two ends of the same coil are lettered *a* and *a′*, *b* and *b′*, and are connected to the sectors of the central commutator in the order shown. In following the connections it will be found that all the coils are united into a continuous circuit, the commutator sectors being traversed in succession, and the signs plus and minus indicate the direction of the circuit induced at any particular spot in the position of rotation shown in the diagram.

"In order to drive so powerful a machine, a steam engine, or other uniform source of power, will be required. As long as the circuit remains unclosed, and the two binding screws are not in metallic connection with each other, the rotation of the drum may be effected by the expenditure of sufficient force to overcome merely the friction in the journal boxes F_1 F_2. If, however, the external circuit is closed, by the introduction of an electric lamp, for instance, the induced currents will at once be developed in the drum, if but a trace of magnetism exist in the armatures N N_1 and S S_1. These currents, by adding to the strength of the electro-magnets, exert a strengthening action upon the armatures, and thereby become themselves strengthened. The quantity of electricity generated by the machine as well as the mechanical power expended in running it, will thus rapidly become greater, since every increase in magnetism is attended by a corresponding increase in the intensity of the current. It is for this reason that, for certain purposes, in producing a *steady* electric light, for instance, a uniform action of the driving engine is absolutely necessary; and all the motors designed to be used in driving dynamo-electric machines must, on this account, be provided with reliable regulating contrivances, in order to secure such uniformity as much as possible.

"In using the machine for the production of the electric light, it may happen that, through any external cause, impurities in the carbons, for instance, the arc becomes extinguished and the current interrupted. In such a case the consumption of power on the part of the machine suddenly falls almost to zero, and a considerable (even dangerous) increase in the velocity of rotation of the drum would be the consequence thereof, were the driving engine to continue working at the same rate without having a corresponding resistance to encounter. In order to meet any such danger Siemens and Halske have provided their machine with an automatic switch, which throws into the circuit an artificial resistance when, through any cause whatever, the circuit is interrupted in the lamps. * * *

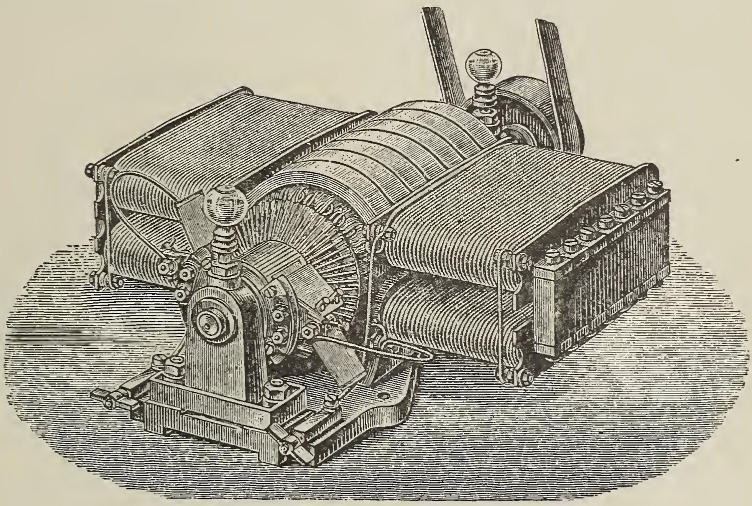


Fig. 24.

"The machine represented in Figs. 21 and 22 has a length of about 10½ centimeters, a height of 32, and a width of 46½ centimeters, and yields, when the drum revolves at the rate of 450 per minute, for which 6 horse-power is required, an electric light of 1,400 standard candles. The current produced by it is capable of heating to redness a copper wire one meter long and one millimeter in thickness.

"In the machines of medium and smallest size, in order to secure the necessary simplification in construction, the iron cylinder is firmly united with the wire coils; and rotates with them. The fixing of this inner armature, on the contrary, is rendered necessary in such cases in which there occurs a very frequent change of polarity, and in which the utmost utilization of the driving power is called for, which is usually only the case with the larger machines.

"Fig. 25 represents in perspective a Siemens-Halske machine (system of v.

Hefner Alteneck), of the latest construction. The electro-magnets have the flat shape of those used in Wilde's machine. The current is taken off by means of metallic brushes, and the large number of radial pieces in the commutator shows that the drum carries a large number of separate coils.

"In the latest machine of this form the commutator disc is done away with, and the ends of the separate wire coils surrounding the drum are connected with each other and led to the radial pieces of the drum-shaft in a somewhat similar manner to that obtaining in the Gramme machine. These radial pieces are insulated from each other by means of asbestos paper. Contact rollers no longer employed, their place being taken by flat elastic bands (brushes) made of silver-plated copper wires.

"The smaller size of these machines is 698^{mm} in length, 572^{mm} wide, and 233^{mm} high; the drum alone is 388^{mm} long, and carries 28 wire coils, and a commutator divided into 56 parts. Its weight amounts to 115 kilogrammes; the maximum velocity of the drum, 900 revolutions per minute; and the intensity of the light produced, 1,400 standard candles. One and a half horse-power is required to run it.

"The medium size differs in construction but slightly from the one just described. It is 757^{mm} in length, 700^{mm} wide and 284^{mm} high; the drum has a length of 456^{mm}, and is also wound with 28 coils; the commutator is, therefore, also composed of 56 pieces, against which wire brushes are made to press. The machine weighs 200 kilogrammes, and produces, with its maximum velocity of 700 revolutions per minute, a light of 4,000 candles. It requires 3½ horse-power."

One of these machines, of the pattern and size last described, together with an electric lamp or regulator by the same maker, was purchased by the Light-house Department at my suggestion, approved by the Board, and has been repeatedly operated under my direction at the Stevens Institute with very excellent results. The numerical expression of these results will be given in comparison with that obtained from other machines at the conclusion of this report.

Passing now to the next characteristically different machine we come to the very remarkable form known as the "Gramme Machine."

THE GRAMME MACHINE.

In 1871 M. Z. T. Gramme, a cabinet-maker, of Paris, presented to the French Academy the description of a new form of magneto-electric machine, possessing several new and remarkable features. Its general structure can be well understood from the accompanying figure, which represents one of its simplest forms as constructed with permanent magnets, and to be driven simply by hand-power.

The large U magnets terminate in heavy end pieces, which constitute massive north and south poles, almost surrounding the armature, which constitutes the peculiar feature of this machine.

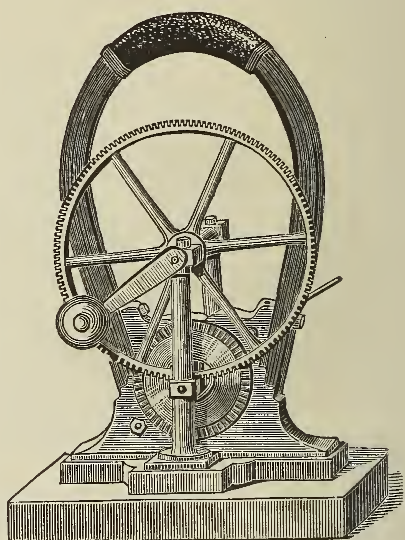


Fig. 25.

This armature consists of a ring made of a coil or hank of soft iron wire, around which are wound a series of coils of copper wire, in the manner shown in Fig. 26, which represents such an armature partially dissected.

The ring made of a hank of iron wire is shown cut across and spread out to some extent, the cut ends appearing below B and at A. The several coils of wire are also represented partly in place above and spread apart in the lower part of the figure. The wire of these coils passes continuously from one to another, but between each makes a loop, which is hooked into a copper conductor, R R, constituting part of the commutator.

The general principle on which this machine acts can best be explained by reference to the diagram (Fig. 27). Let S and N represent the poles of the permanent magnet, and the divided ring between them stand for the ring of iron wire.

This ring, under the influence of the poles S and N, will always have a north pole at *n* and a south pole at *s*, the parts *p* and p_1 being neutral, or, in other words, will correspond with two semi-annular magnets with their north poles together at *n* and their south poles together at *s*. The magnetic currents in the various parts of this ring will then be represented by the arrows drawn on it. As the ring rotates, these poles will always maintain essentially the same

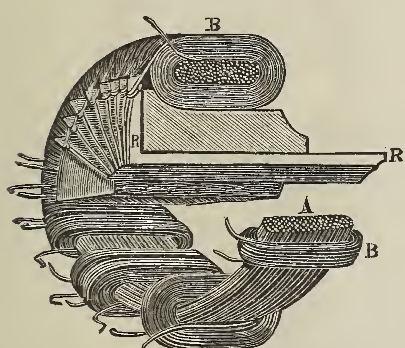


Fig. 26.

position in space, and, therefore, in relation to the coils wound on this ring, we might assume that this inner ring was at rest, and that the coils above were carried round over it.

Now let R indicate such a coil, and suppose it to move toward the right; it will evidently leave more magnetic currents in a given direction in the left-hand semi-annulus than it approaches, and will therefore acquire a current in the direction shown by the arrow, to which will be added the effect due to approaching the opposite currents in the upper part of the right-hand semi-annulus. At *n*, and also at *s*, this action will reach a maximum, as the coil will be (at *n*, for example) approaching all currents of the right-hand semi-annulus and leaving all those of the left, and *vice versa* at *s*. At *p* and p_1, however, the effect will be *nil*, as the coil would there approach and leave equal numbers of currents of like direction.

Now if we consider a number of coils all moving around from left to right, on the upper part of the ring, the currents in them will have the same direction; and if they are all connected together these currents will aid each other, and may be taken off by conductors pressing on the commutators at *p* and p_1. Let us suppose that the current is such as to make p_1 positive and *p* negative. As the coils pass p_1 the direction of the currents in them is reversed, but so also is their relation to the conductor or commutator. Thus, a coil which was coming toward p_1 from above was sending its positive current forward toward p_1; as it leaves p_1, going onward below, its current being reversed, it no longer sends its positive current forward, but sends it back to p_1, which it has passed. Thus p_1 gets not only the positive current from the coils on the upper half of the ring, but from those also on the lower half.

By reason of the action which has thus been described, there is in the first place no rapid reversal of magnetism in the iron core of the armature, as in the Wilde machine, but only a continuous and progressive change as the ring rotates; and in the second place there is a continuous current of electricity in a constant direction, with only one reversal for each revolution of the entire set of coils.

Of course the method of passing the current of one machine through the coils of an electro-magnet replacing the permanent magnets shown in Fig. 25, could be carried out with this machine just as with Wilde's; or the machine itself, being made with electro-magnets, these could be excited by its own current, as with the machines of Ladd and of Siemens, which we have already described. This last plan was, in fact, at once adopted, and the standard Gramme machine was made in the form shown in Fig. 28.

Here the electro-magnets consist of the large horizontal cylinders seen above and below, so wound with wire as to produce a combined north pole at the center above, where the extension piece is attached, and a corresponding south pole below.

Within and between these extension pieces is the armature or bobbin, consisting of the iron ring wound with its numerous flat coils. The connections in this case are carried out on both sides of the axis, and thus several pairs of brushes can be applied, and numerous currents taken off.

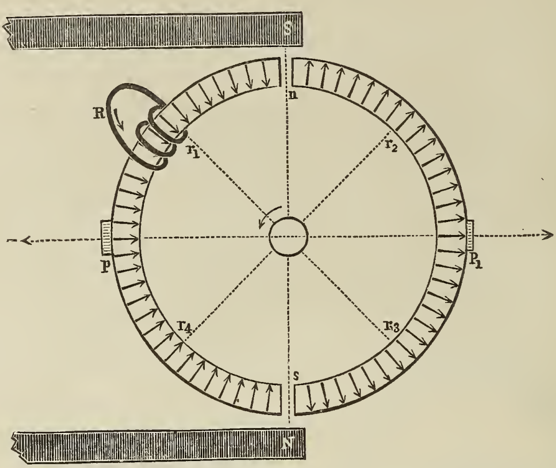


Fig. 27.

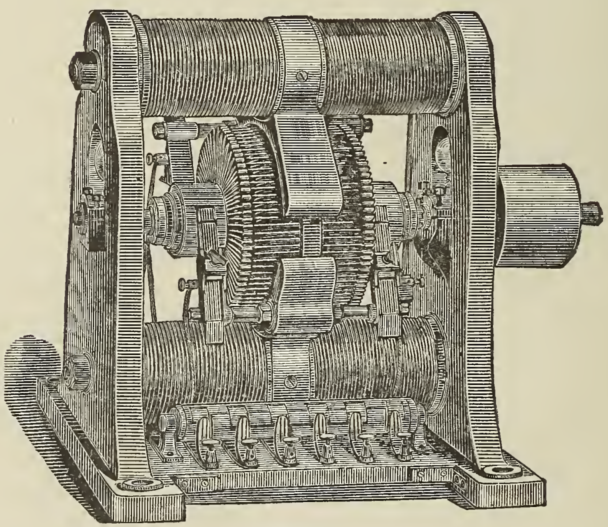


Fig. 28.

With all these machines, however, the best effects are obtained by employing only one circuit, or passing the whole current from the bobbin through the electro-magnet coils and the exterior circuit, where it is used.

In 1873 Wilde described a new form of magneto-electric machine, in which he abandoned the use of the Siemens armature, and returned, in general structure, very much to the form of the old Alliance machine.

Two sets of electro-magnets, 16 in each, were arranged in such a way that they formed two hollow cylinders opposite each other, with the poles of the magnets of each cylinder facing each other, but having space between for another cylinder of 16 electro-magnets, mounted parallel with the others, and carried by a disc of iron, from which they projected at each side. In fact, there were three cylinders of magnets, all having a common horizontal axis; the outer ones fixed and the inner ones radiating, so as to carry its magnets between the poles of the others.

Good effects were obtained with this machine, and the heating of the armatures was avoided, but it was not found to equal the improved Siemens or the Gramme in efficiency or economy of power.

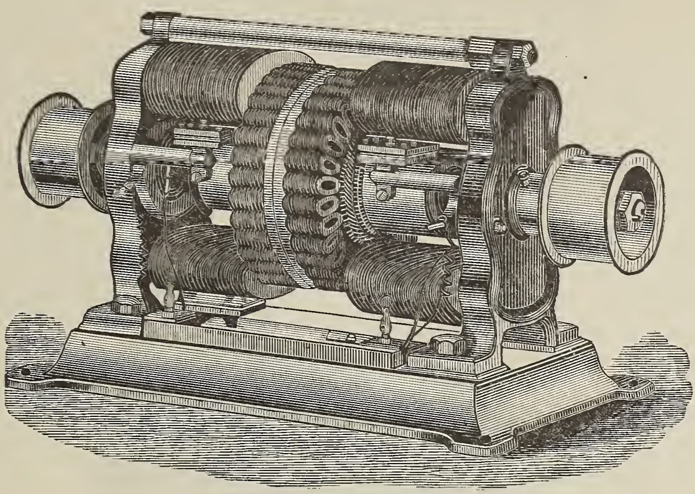


Fig. 29.

In 1875 a patent was taken out in the United States by Mr. Moses G. Farmer for a machine essentially like that of Wilde, just described. This, with some modifications of details, is now manufactured by Wallace & Sons, of Ansonia, Connecticut, and has come into very general use.

In the experiments made by the present writer, as well as those conducted by the Franklin Institute, this machine seems to be inferior in "duty" to some others; but the conditions of such trials are so difficult to establish, in adapting the nature of the exterior circuit, including the lamp, to the peculiarities of each machine, that I should not regard these conclusions as absolutely final.

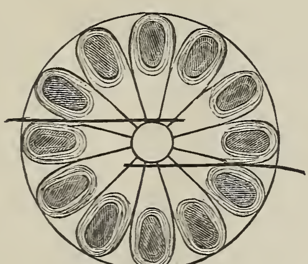


Fig. 30.

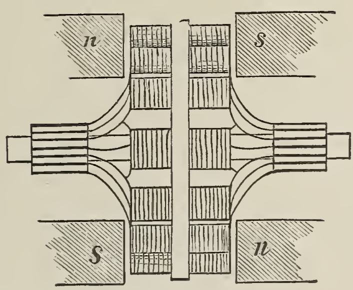


Fig. 31.

In the Wallace-Farmer machine (Fig. 29) the magnetic field is produced by two horse-shoe electro-magnets, but with poles of opposite character facing each other. Between the arms of the magnets, and passing through the uprights supporting them, is the shaft, carrying at its center the rotating armature.

This consists of a disc of cast iron, near the periphery of which, and at right angles to either face, are iron cores, wound with insulated wire, thus constituting a double series of coils. These armature coils (Figs. 30 and 31) being connected end to end, the loops so formed are connected in the same manner, and to a commutator of the same construction as that of the Gramme. As the armature rotates, the cores pass between the opposed north and south poles of the field magnets, and the current generated depends on the change of polarity of the cores. It will be seen that this constitutes a double machine, each series of coils, with its commutator, being capable of use quite independently of the other; but in practice the electrical connections are so made that the currents generated in the two series of armature coils pass through the field-magnet coils, and are joined in one external circuit. This form of armature also presents considerable uncovered surface of iron to the cooling effect of the air, but its external form, in its fan-like action on the air, like that of the Brush, presents considerable resistance to rotation. In the Wallace-Farmer machine there was considerable heating of the armature, the temperature being sufficiently high to melt sealing wax.

Another machine made and used in this country to a considerable extent is that of Mr. Brush, manufactured by the Telegraph Supply Company, Cleveland, Ohio. This is shown in Fig. 32.

The Brush machine has for its magnetic field two horseshoe electro-magnets,

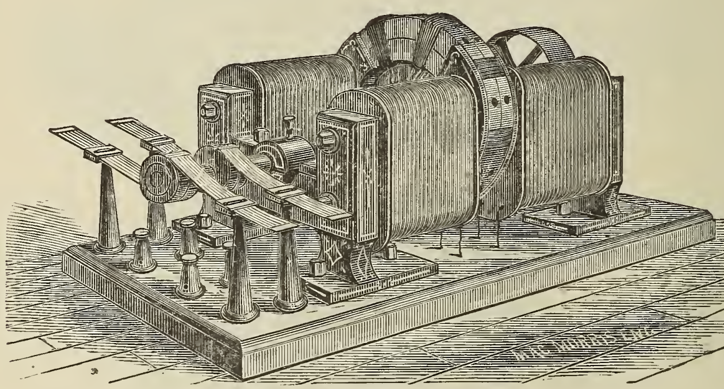


Fig. 32.

with their like poles facing each other, at a suitable distance apart, the circular armature rotating between them.

In this machine the currents are generated in coils of copper wire wound upon an iron ring, constituting the armature. This ring is not entirely covered by the coils, as in the Gramme armature, but the alternate uncovered spaces between the coils is almost completely filled by iron extensions from the ring, thus exposing large surfaces of the armature ring for the dissipation of heat, due to its constantly changing magnetism, as in the Pacinotti machine.

The ring revolves between the poles of two large field magnets, the two positive poles of which are at the same extremity of the diameter of the armature, and the two negative poles at the opposite extremity, each pair constituting practically extended poles of opposite character.

The coils on the armature ring are eight in number, opposite ones being connected end to end, and the terminals carried out to the commutator. Figs. 33 and 34 show this arrangement, only one pair of coils, however, being shown in Fig. 33 as connected. In order to place the commutator in a convenient position, the terminal wires are carried through the centre of the shaft to a point outside the bearings.

The commutators are so arranged that at any instant three pairs of coils are interposed in the circuit of the machine, working, as it were, in multiple arc, the remaing pair being cut out at the neutral point; while in the Gramme machine, the numerous armature coils being connected end to end throughout, and connections being made to the metal strips composing the commutator, two sets of coils in multiple arc are at one time interposed in the circuit, each set constituting one-half of the coils on the armature.

The commutator consists of segments of brass, secured to a ring of non-conducting material, carried on the shaft. These segments are divided into two thicknesses, the inner being permanently secured to the non-conducting material, and the outer ones, which take all the wear,

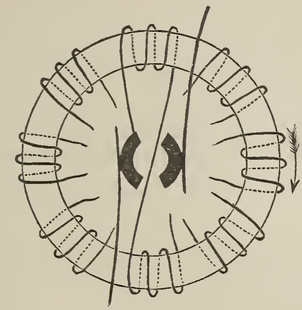


Fig. 33.

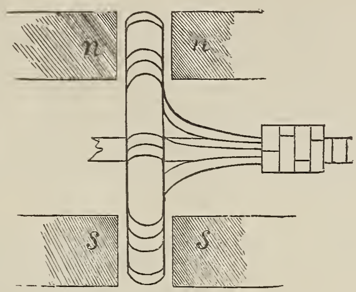


Fig. 34.

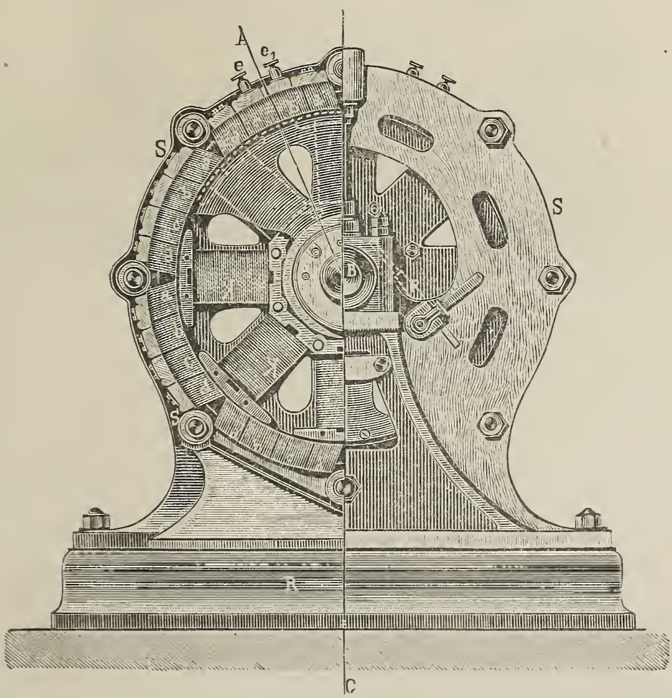


Fig. 35.

are fastened to the inner in such a manner that they can be easily removed when required.

The commutator brushes, which are composed of strips of hard brass, joined together at their outer ends, are inexpensive and easily renewed. The high speed at which these machines are run, together with the form of the armature, causes the rotation of the latter to be considerably resisted by the air, and producing a humming sound, but otherwise they run smoothly, the heating of the armature being inconsiderable—not exceeding 120° Fahr. after four and three-quarter hours' run.

Another dynamo-electric machine which has been operated with much success in many places is that of Mr. Hiram S. Maxim, of New York.

In general construction it much resembles the Siemens machine as to its field magnets and the Gramme machine as to is armature, though there are differences more or less important in both. The armature is like the Gramme in consisting of a series of coils arranged into an annulus, but this annulus is lengthened until it becomes a drum or cylinder. In place of an iron-wire core, this ring or drum of coils has a series of thin iron rings, so cut from sheet-iron as to escape having any fiber in the direction of their circumference.

Two of these machines have been thoroughly tested in the course of the experiments herewith to be reported, and have shown themselves to be very efficient.

When the Jablochkoff candle came into vogue it became highly important to go back in one of the directions in which

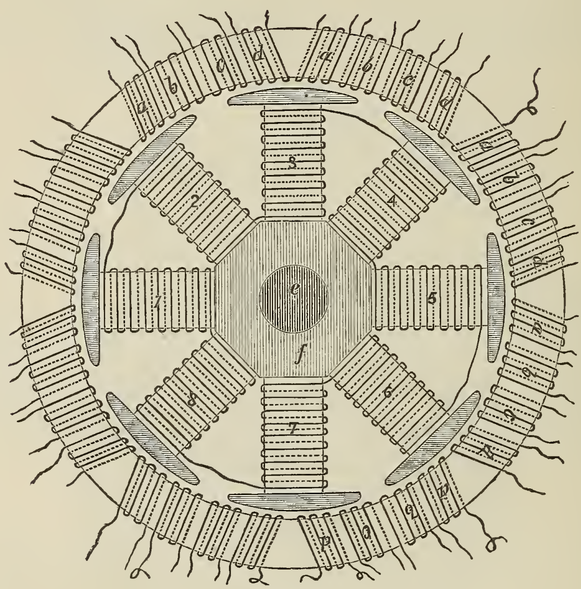


Fig. 36.

improvement had been made in most of the recent machines, and produce a machine which should yield alternating or reversing currents, in place of those passing continuously in one direction. This was necessary to equalize the consumption of the two parallel carbons of the Jablochkoff, and also even with other lamps, for purposes which we will explain further on.

To meet this requirement Gramme has arranged a machine which not only produces alternating currents, but operates readily, at the same time, a number of separate circuits. It is these machines which were recently used during the exposition to light certain streets and public places in Paris. The general appearance of this machine is shown in Fig. 35.

This machine, it will be observed, differs radically from the continuous-current machine of Gramme.

In the first place, it is, as it were, turned inside out. Thus there is a magnetic ring wound with successive coils, but this, in place of revolving within the field of fixed electro-magnets, is stationary on the outside, while a series of eight electro-magnets, excited by a separate machine, rotate in the interior of this fixed armature ring.

The principle of the machine will be readily understood from the diagram Fig. (36).

The interior system of electro-magnets is so wound that the polarity of each spoke is reverse to its neighbors. These magnets, therefore, by induction develop eight consecutive poles in the soft iron of the surrounding ring, and, as they revolve, the poles of this ring move with them. Thus, while in the older Gramme machine the actually moving ring had poles stationary in space, over which the coils passed, in this case the actually stationary ring has moving poles which pass through the stationary coils.

These coils are wound in eight sets, each alternate set being wound in an opposite direction, and each set is made up of several separate coils, to facilitate the making of all sorts of combinations, which are most easily arranged in this machine, as no commutators are used, and all the coils are fixed.

If all the coils marked *a* are connected together, it is evident that at any moment the currents in all of them will be in the same direction. Thus, suppose the electro-magnet spoke 2 to have a north pole at its outer end, and 3 to have a south pole similarly situated; then as 2 moves over *a* it will produce a current alike in direction to that produced by the opposite pole of 3 moving over the oppositely wound wire of the next coil marked *a*.

Of course, as the magnet 2 leaves *a* and the oppositely polarized magnet 1 approaches, this current will be reversed in the first coil marked *a*, and also likewise in the second coil *a*, for a like reason.

It has been stated that these machines worked one Jablochkoff candle for each horse-power consumed, but several who watched their actual running say that very much more power was actually consumed.

PICTET'S PROPOSAL TO DISSOCIATE THE METALLOID ELEMENTS.

From "Nature."

During the last two years M. Pictet has published several important memoirs upon different branches of thermo-dynamics, and has, as is well known, in his researches on the liquefaction of oxygen and of hydrogen shown the fruitfulness of the ideas which have thus occupied him. He is at the present moment engaged upon a large volume entitled *Synthèse de la Chaleur*, a work in which it is sought to deduce all the known laws of heat from the general principles of theoretical mechanics, by finding true mathematical definitions for the quantities which hitherto have been usually expressed as simple experimental matters. Thus the terms "temperature," "specific heat," "latent heat," &c., are capaple of exact definition in a manner which enables the relations between them to be investigated analytically. These relations thus investigated are found by M. Pictet to be capable of experimental verification, and the complete accordance of deduced theory with observed fact justifies him in giving the name of *Synthesis of Heat* to this new advance in thermo-dynamics.

To understand aright the views of M. Pictet, with respect to the possible dissociation of the metalloids, we must notice briefly the fundamental points of his theory of heat. If the atoms of a body are in absolute rest and equilibrium, their temperature will be at *absolute zero*. If, however, kinetic energy is imparted to these atoms and they are set vibrating, the *temperature* of the body will be represented by the *mean amplitude* of the oscillations, and the total *quantity of heat* in the body will be the quantity of energy thus imparted.

Now the great decomposing force in nature is heat. It is heat which changes solids to liquids, liquids to vapors. Heat breaks up chemically combined substances and reduces them to simpler forms. It is quite certain that the limits of the power of the chemist to decompose the substances that pass through his hands are those which correspond to the temperatures which he can produce in his laboratory. We shall explain at a later portion of this article how this comes to be the case. Yet there are in nature temperatures far more elevated than the highest artificial temperature. To take the most striking example, the surface of the sun must be enormously hotter than even the hottest of the electric arcs in which even the most infusible of metals is vaporised. We know this upon evidence which acumulates every day, and of which the most important is that afforded by the spectroscope. The researches of Kirchhoff and J. W. Draper, and the later work of Cornu, Mascart, and Lockyer, establish incontestably that the radiation emitted by a glowing substance varies with the temperature of the substance, and that at higher temperatures new rays of shorter wave-length and more rapid oscillation appear, while the intensity of all the emitted rays is also greater. The solar spectrum is much more rich in violet and ultra-violet rays at the more refrangible end of the scale than the spectrum of any artificially heated substance. The irresistible conclusion is that its temperature is far higher.

But the spectrum of the sun when scrutinized with the most elaborate skill and knowledge reveals another very striking circumstance. A large number of the substances regarded by the chemist as *elements* have now been recognized by the characteristic absorption lines of their spectra as existing in the heated matters surrounding the sun. The researches of Mr. Lockyer show that nearly forty of the metals are thus to be detected. But *not a single metalloid* is thus discoverable. Indeed so marked is their absence that the presence of hydrogen in such great abundance is held by no less an authority than Mr. Dumas to be a convincing proof that hydrogen is a metal and not a metalloid. It is true that Mr. Henry Draper of New York, has announced the discovery of *bright* lines corresponding to oxygen amongst the dark absorption lines of the solar spectrum; but it is far from certain whether the coincidence he has pointed out is real or apparent only, and all other evidence points to an adverse conclusion.

Putting together these two capital facts of solar spectroscopy, the irresistible inference is that the surface of the sun is too hot for metalloids to exist there; or in other words, *its temperature is higher than the temperature of the dissociation-points of the metalloids.* This term dissociation-point is justified by analogy with the terms boiling-point and melting-point, with which we are familiar, and with which we associate the notion of definite temperatures.

Let us examine, following M. Pictet's fundamental principles, how far this analogy can be followed out and justified. Those fundamental principles are that in hot bodies the molecules are swinging to and fro about positions of equilibrium; that "heat" *is* the energy of these molecular vibrations; and that the "temperature" of the body *is* the mean amplitude of the vibrations. If more energy is imparted to a solid, the more energetically will its particles oscillate, the longer will be the mean amplitude of their oscillations, and the higher the temperature. If we allow that the gravitation law of attraction, namely that the attraction between two masses varies inversely as the square of the distance between them, holds good not only on the grandest scale but also on the most minute, we must admit that the force acting on a vibrating particle at the furthest limits of its swing, and tending to attract it back, will be relatively weak as the amplitude of the swing is great. Hence too long a vibration may carry the particle right beyond the field of molecular attraction; and the particle will not return but will carry off with it in the form of potential energy part of the heat furnished to the body. The sum of these small quantities of potential energy which must necessarily disappear from the body during its change of state from the solid to the liquid condition constitute that which we usually term "latent heat."

Now consider a solid body at the absolute zero of temperature to which new quantities of heat are continuously imparted. What will be the successive changes to be observed? At first the temperature of the body will rise proportionately to the quantity of heat imparted to it. When the vibrations of the particles have attained a certain amplitude, fusion will take place, not all at once but gradually, each molecule passing away from the attraction of its neighbors, as soon as its vibration is sufficiently energetic. Each solid particle will thus be split up into two or more liquid molecules exactly resembling each other. Every one of these molecules will require potential energy, hence during the entire process of liquefaction, the whole of the heat imparted will be employed in producing the change of state; so that the temperature will be stationary in spite of the continual addition of heat. But when the whole substance has melted, the temperature will again rise up to a certain point determined by the commencement of ebullition, a point which will vary with the conditions of external pressure. This second change of state arises from a further splitting up of the molecules into two or more portions each, every separated portion again carrying off with it a further quantity of potential energy, the "latent heat" of vaporization. If the gaseous molecules thus produced receive still further quantities of heat, the temperature will go on rising until another point is reached, corresponding to a first chemical *dissociation*, when, as the lengths of oscillations become excessive, the separate atoms are successively thrown apart. This process, like those of liquefaction and vaporization, will be accompanied by the absorption of heat. The extent to which energy must be furnished in order thus to produce chemical separation, will be proportional to the chemical affinity of the separated atoms; and if the body consists of several chemical constituents it is probable that some of these will be dissociated at lower temperatures and some at higher. The limits of dissociation will have been reached when the body has been separated into its ultimate particles or true elements.

The striking feature of this series of changes is—that while the addition of quantities of heat goes on continuously the rise of temperature is discontinuous, having several stationary points in the range between the absolute zero and the highest possible temperature; each fresh stationary point corresponding to a change of state, or a decomposition of the particles into simpler forms.

Suppose next that we could reverse the order of operations, and could abstract the heat continuously from the dissociated bodies, we might expect to find the same series of changes occurring in the inverse order. But this expectation would not be realized, for reasons which are not difficult to find. In the two changes of state which are of a nature usually termed *physical changes*, namely liquefaction and vaporization, the result of the splitting up is to produce particles all of the same kind. In a liquid — water, for example — all the liquid particles are water. In a vapor —steam, for example—the particles are all particles of steam. But in the case of *dissociation*, which is a *chemical* change of state, the result of the splitting up is to produce particles not all of the same kind. Thus, if steam is passed through a white hot platinum tube, the dissociated matters are of two kinds, oxygen particles and hydrogen particles. In the changes denominated "physical" which produce homogeneous particles, the recombination does not depend on the relative *positions* of the constituents but only on *pressure* and *temperature*. In the changes denominated "chemical" which, as we have seen, produce heterogeneous particles, the recombination of the constituents depends on their relative *positions* and on the way in which they have to be grouped in the compound, as well as on pressure and temperature. This most important distinction must not be overlooked.

Again, the dissociated chemical atoms carry away with them in a potential form the heat which has disappeared during the process of dissociation, exactly as a liquid carries in a potential form the "latent heat" which disappeared during the process of liquefaction. If we collect the separated chemical constituents—the oxygen and hydrogen for example—and make them recombine, they will evolve this potential energy and the heat will reappear. The limit of temperature, therefore, which can possibly be reached by the combustion or chemical combination of any bodies is precisely the temperature of the dissociation point of the substances formed. Hence there is obviously, as we remarked at the outset, a limit to the power of the chemist to dissociate bodies; a limit determined simply by the temperatures he can artificially produce.

It will be remarked, however, that we have in the electric current a means of obtaining many decompositions which without its aid would have been unknown to us. We may even assert upon the certain evidence of the spectroscope that the temperatures attained by the electric spark are far higher than those of any known combustion. Nevertheless there are here also limits which cannot be passed. If in the circuit of the most powerful battery we interpose a conductor of considerable resistance its temperature will rise; and if the conductor be reduced in thickness to augment its resistance, will continue to rise until the conductor itself is either liquefied, volatilized or dissociated, when of necessity a practical limit is reached in the entire stoppage of the current. Again, with the discharges from induction coils and Leyden jars, which take place even across gases, there must be a limit, determined by the absorption of energy by the very molecules which are concerned in the discharge, and whose resistance to the electrical action will increase with their temperature. It is a point which may admit of some further discussion. But, on the whole, one is led to the conclusion that the dissociations we have shown to be theoretically possible are in a very large number of cases absolutely beyond the practical limits of experimental achievement.

One course yet remains open. We have not hitherto considered the connection between temperature and radiation in its bearings upon this question. It appears that every temperature, as defined above, corresponds to a definite kind of radiation. Every calorific oscillation of a particular rate is then associated with the propagation of a wave of disturbance in the surrounding ether; this wave having a particular frequency, or, what is the same thing, a particular wave-length. When these calorific waves in passing through space meet a body they tend to set its particles vibrating; and, what is more important, tend to set them vibrating in unison with the original vibrations of the radiating source. If it were not that the receiving body were subjected to external influences, it would acquire little by little exactly the same temperature as the body from which the radiations were emitted. In other words, thermic equilibrium would be established between the two, quite irrespective of the distance between them. We know that the rays of the sun traverse space without any diminution in their frequency or wave-length. It follows, therefore, *that the sun's rays are able to raise to a temperature equal to that of the sun's surface any body on the surface of the earth on which they can be concentrated*, provided only such a body could be preserved from losing heat by conduction or radiation. Although a certain quantity of the solar radiation is arrested by absorption in the imperfectly transparent atmosphere surrounding the earth, measurements made at places so widely apart as Cairo, Paris, and St. Petersburg agree in showing almost identical values for the amount of heat received from the sun, and which is about twelve calories, per square meter, per minute.

Now on the supposition that all the metalloids, with the exception, perhaps, of oxygen, are dissociated in the sun, thermal equilibrium, if thus experimentally obtained, ought to affect the dissociation of them upon our globe also.

M. Pictet therefore proposes that an enormous parabolic mirror should be constructed, in the focus of which the sun's rays should be concentrated upon the various metalloids which it is sought to decompose. All the data for calculating the requisite size of the mirror are known to a certain approximative value, with one exception. We know the quantitative intensity of solar radiation, and the reflecting power of polished metals, and hence can calculate how many units of heat a mirror of given size will hurl into its focus per minute. *We do not know* how much heat must be furnished to a given weight of any one of the hitherto undecomposed metalloids to dissociate it, but we are quite certain that this quantity must be much greater than that produced by the combustion of an equal weight of hydrogen and oxygen. Assuming that to dissociate bromine required *a hundred times* as much heat (at the temperature of its dissociation-point) as water vapor requires (at *its* dissociation-point) to split it up, M. Pictet calculates that a single gramme of bromine must have 350 calories expended upon it to resolve it into its elements. Further calculation leads him to consider that to dissociate one gramme of bromine per minute, would require that the solar rays should be concentrated by a mirror of *at least* 35 square meters of surface, measured normally to the rays, or of about ten meters' aperture. It would, he thinks, be best constructed in separate pieces of about a square meter in area, each ground and polished to a true curve and mounted in a special frame. The depth of the mirror should be equal to half its aperture, bringing the focus into the plane of the rim. At the focus would be a special *solar chamber*, or crucible, constructed of lime or zircon, or other refractory substance, into which the vapors to be operated upon would be led. To avoid loss of heat it would be kept hot from without by oxyhydrogen flames. The whole apparatus ought not, he thinks, to weigh as much as two tons. To catch and retain the dissociated substances, and to prevent their immediate recombination, he proposes to aspirate the vapors of the chamber through metal tubes containing metallic gauze, and cooled from without to a temperature perhaps as low as 50° by intense artificial refrigeration. The rapid cooling thus produced should hinder at least a considerable proportion of the constituents from recombining as fast as they were liberated from each other in the solar chamber.

There is much that is suggestive in the proposals of M. Pictet; so much, indeed, that any attempt at criticism or comment would outrun the limits of this article, which is therefore simply devoted to the exposition of M. Pictet's ideas in phrases as nearly identical as possible with those in which he has himself expressed them.

ON THE STRENGTH OF IRON AND STEEL UNDER MOVING LOADS.

By H. LIPPOLD.

From "Organ für die Fortschritte des Eisenbahnwesens."
From the "Abstracts," translated for the Institution of Civil Engineers.

The author begins by quoting a general law, derived by Wöhler fron his experiments on railway axles: "A material may be broken by repeated oscillations of load, no one of which produces a strain equal to the breaking strain. It is then the differences between the alternate strains in opposite directions which destroy the cohesion of the material, and the absolute intensity of the strain has only an influence so far that the higher this intensity the smaller are the differences which are sufficient to produce rupture."

Wöhler's experiments were made, first with actual axles, and afterwards with bars about five inches square, revolving under heavy loads. The highest speed was, however, one revolution per second, whereas the wheel of a train at thirty-five miles per hour makes about five revolutions per second. Consequently his results compare better with the cross girders of a railway bridge, which are suddenly put under strain by the advance of a train; but they differ from these inasmuch as in the latter case the strain, once put on, is maintained until the whole train has passed, *i. e.*, for several seconds. This longer duration of strain has a great effect in causing rupture, as is shown by two sets of experiments of Wöhler's, in one of which there were four oscillations during each revolution of the bar, and in the other case one oscillation only, the strain being kept on for three-quarters of each revolution. In the former case the iron withstood 732,572 oscillations, as against 170,900 in the latter. The reason of this fact, doubtless, is that the permanent set, and even the temporary deformation of the material, requires a certain time for full development. It is very desirable that further experiments should be made on this point.

The influence of the speed of the moving load is next considered. The effect of this on the deflection appears to be very slight. In a report on the testing of Prussian railway bridges (1862) it is stated that the greater or less speed of passing trains, up to forty-five miles an hour, produced no sensible variation in deflection in most cases, and never more than a very slight one. It does not follow, however, as Wöhler supposes, that the effect of speed may be neglected. Suppose a train to advance on a bridge very slowly, then the material at the center is only brought very slowly to its maximum stress; consequently it has ample time to take up the strain or deformation corresponding to that stress, and no oscillations follow. But suppose the train to advance rapidly; then the maximum stress comes on rapidly, and produces oscillations about the point of the maximum strain, the effects of which are more severe as the velocity increases. The reason why this does not appear in the total deflection is that the time of oscillation of any one piece varies as the square foot of its length; hence, as the pieces of which the bridge is composed are of various lengths, their oscillations interfere with each other, and the total deflection may thus be even less than with a stationary load, as has been actually observed in at least one experiment. In riveted bridges, the deformations caused by the rigidity of the joints also come in to complicate the result. The dynamical effect of the moving load must, therefore, be taken into consideration, and this can only be done by assuming the worst possible case, viz: where the train comes on instantaneously. For this purpose Wöhler's principle is re-stated as follows: For the breaking of a piece a certain quantity of work is necessary; and this work may be done upon it either at once or by repeated applications of loads, provided that the latter succeed each other so rapidly as to produce oscillations.

The testing of a bar of iron or steel, by slowly applied loads increasing up to rupture, is known to fall into three periods. In the first, the elastic extension is proportional to the load, and the permanent set so small as to be neglected. The limiting load of this period the Author calls the original limit of elasticity. In the second period, the elastic extension is proportional to the load, but the permanent set increases in a higher proportion. In the third, the permanent set increases much more rapidly, but the elastic extension remains proportional to the load up to rupture itself. The increase of set is partly due to the contraction of the bar in the immediate neighborhood of the point of ultimate rupture. The amount of this contraction depends on the section; and hence the permanent sets in this third period are not proportional to the length of the bar. If, in the second period, the same load is again applied, the Author considers (on what ground he does not state) that no increase of permanent set takes place; consequently, the elastic extension is the only extension which occurs, and thus, practically, the limit of elasticity has been raised so much beyond its original limit. The whole process is represented graphically by a curve, of which the ordinates are loads, and the abscissæ extensions. The area of this curve, measured up to any ordinate, represents the work done by the corresponding load. But it is known that a load applied suddenly will produce the same extension as double that load applied gradually. Hence, within the limit of elasticity, a suddenly-applied load will do the same work as double that load applied gradually; and by what has been said the limit of elasticity may be raised to any point short of rupture by repeated applications. Hence it follows that repeated and sudden applications of a load cannot produce rupture, unless it exceeds half the breaking load; also, that the final result of such a load is to produce the same effect as a gradually applied load of double the amount. These conclusions are confirmed by Wohler's experiments on steel, where the lowest stress which produced rupture by sudden repetitions was almost exactly half the absolute breaking stress. With iron this is not the case, as the value of the absolute breaking stress appears to be raised by the repeated loading. In a similar manner, when a piece is already loaded with a strain P, may be found the greatest additional load which can be suddenly and repeatedly applied without causing rupture. It appears that this equals $\frac{P+B}{2}$, where B is the absolute breaking stress. The examination of a particular example from Knut Styffe's work confirms these general conclusions. A table annexed gives, in addition to the strains and extensions, the work done in bringing on the strain slowly, and so producing the extension; and also the suddenly applied load which would produce the same result. An examination of this table clearly shows the diminished effect of the sudden load, in cases where it is not given time to produce its full extension; the remainder of the work is of course converted into heat, which might easily be registered in future experiments by the use of the thermo electric pile. The table further gives for each state of strain the additional sudden load which would at once produce fracture, and the greatest additional sudden load which would fail to produce fracture, even when repeated any number of times.

All circumstances of strain which cannot be reduced to actual calculation must be allowed for by the factor of safety. These, which continually diminish in number as science progresses, are mainly the following: the influence of rigid joints in riveted bridges; the shocks arising from inequalities in the permanent way, or in the movement of the vehicles; and the defects in construction, or differences of strength in the materials employed. They may be brought to a minimum by various practical regulations. From an example it is deduced that the influence of the unknown stresses arising from shocks may be as great as that of the moving load, and that they may be allowed for by taking the ultimate strength of the structure, or the limit of elasticity, at $\frac{7}{10}$ of its real value. The unequal stresses arising from rigid joints are more troublesome, as it is quite impossible to examine their nature. On the whole, however, it will suffice to lay down the principle that a structure must never be loaded with a stress greater than $\frac{7}{10}$ of its limit of elasticity.

These general principles are applied to the case of the working live loads of permanent structures, and formulæ are deduced from them. From these and from experiments it would appear that when alternate tensile and compressive strains are rapidly brought upon a structure, the ultimate strength is not much affected in the case of iron, but is decidedly reduced in the case of steel. In view of the increasing use of the latter material, this result seems to demand further investigation.

HISTORICAL BRIDGES.

From "The Building News."

The recent disaster on the Tay recalls to mind some memorable associations connected with the history of bridges. Our examples, however, will be taken from periods long anterior to that of what has been described, whether inaptly or not, "wirework architecture." The literature of the subject is superabounding, from the days of Vitruvius to those of Vignolles. The motto of the ancient Romans was—First, a highway, next, a bridge. Without it, armies were checked in their advantage; commerce was impeded; social intercourse became almost impossible. The same truth has held good in all ages; from the scheme of Darius, designed for the invasion of Thrace, across the Bosphorus; the famous structure thrown over the Danube by the Servians of the fourteenth century, to assist in the defence of Nicopolis, and those which were projected by Pyrrhus across the Adriatic, by Caligula across the Tyrrhene Sea, and by Cæsar across the Rhine. Many a tradition has come down to us concerning the bridges over the Tiber, the Ælian, and those of the Holy Angel; of the Consuls, and of the Lady, with its "symphony" arches; and their ancient chronicles, in respect of calamity and destruction, are much in accord with those of others, more modern in type, at Avignon, Ay, Bordeaux, Luzon, St. Esprit and Aveyron—with its eighteen arches, once partially wrecked by such a storm as lately swept the Tay. Similar vicissitudes have occurred in France to the "Royal Bridge," of the Tuileries; to that of Lyons, which, like the other at Aveyron, had eighteen arches; to that of Toulouse, across the wide and swift Garonne; to the Farnese, at Parma, and to many besides, which have left their relics along the Flaminian Way. Next to the temples and palaces of a country, its history has, perhaps, been most truly told by the ruin, or the neglect, of its bridges. They bespeak, moreover, something characteristic of the Government, and the manners that once held sway. Those of Rimini were approached through marble porticoes. Those on the road from Trent to Bassano, carried over stupendous gorges, from one giddy height to another, told of sudden flights, and the breaking down of an enemy's means of passage. In a modern epoch, Arcola and Lodi were the centers of tremendous battles, and in all strategy the "head of the bridge" has been regarded as a vital point. It is worthy of remark, moreover, from a different point of view, that among all the three hundred and fifty-nine older bridges of Venice, not one has ever been permitted to fall into decay. And yet, they were only built for foot-passengers, in a city where wheeled vehicular traffic was practically unknown. Those of Amsterdam and Rotterdam scarcely belong to the category. The historical structures now referred to differed, of course, in many repects, though not in all, from those with which the modern and popular mind is familiar. They had nothing in common with the fabric that lately spanned the Tay, with the Menai, or its Tubular neighbor. There was no Niagara for the ancients to bridge; but Trajan had to rear his arches a hundred and fifty feet above the flow of the Danube, and to give them an ample breadth simultaneously. But that which Trajan raised his successor leveled. "A bridge," said the one, "is the means of promoting intercourse and commerce." "A bridge," said the other, "is an invitation to an invader." But the foundation piles, to this hour, remain; and every now and then, are drawn up from the bed of the river. It is, perhaps, hardly reasonable to include, among edifices of this class, that of Xerxes, on the Hellespont, only temporary in its character and purpose, any more than that which was reported to have been thrown by Alexander across the Ganges; but it will be well for modern Europe, if it can present, after a similar lapse of time, such an illustration as the Ælian Bridge, built by Hadrian, and now known as the Bridge of the Holy Angel, at Rome. We have had examples of apparent indestructibility in England; and certainly, those of the Thames, from Westminster downwards, would seem to challenge the efforts of both tide and time. Westminster itself, Waterloo, Blackfriars, and London, suggest, in their several ways, the idea of architectural immortality; but it is to remembered that the Roman works of this class were not all equally durable. Thus, the "Triumphal Bridge" of the Cæsars, still encumbers the Tiber with its fragments, though the Janiculan stands steadfast, while the Ostine has survived to be re-named the bridge of St. Bartholomew. So, the classic Tarpeian is now the Caspi; the Senator's, on the Palatine, was christened the Holy Maria; the Horatian, one of the most beautiful in Rome, and of which only a few scarcley-distinguishable relics remain, would have been re-named, had not a second structure been erected above the first, more like a portico, or a triumphal arch, than a bridge, so aspiring were its proportions, and the bound of its central arch. The bridges of Avignon—long ago a ruin—of Lyon, on the Rhone, and of St. Esprit, were all designed in imitation of these.

Among Italian historical bridges, that constructed by Alexander Farnese, Duke of Parma, was, perhaps, the most architectural, nothing of this character being claimed by the celebrated one "of sighs" at Venice. Palladio, in his day and generation, was great in the design of these structures, as witness that of Rimini already mentioned, on the Flaminian Way; that of Vicenza, on the river Bachiliogni, and that of Verona. But his grandest conceptions were never carried out. One among them represented a bridge which should be composed of several streets, along which no vehicle should ever be allowed to pass, of lodges, porticoes, and statues of marble and bronze. At Madrid there is an edifice—that of the Marzanani—which may almost be described as at once a bridge and a gate, while in the little town of Munster, on the Navante, was formerly constructed a bridge of a single arch, far surpassing in boldness that of the Rialto, at Venice, though this latter has often been eulogized as a masterpiece of Michael Angelo's genius. Palladio bore in mind, as a bridge architect, the necessities which have to be encountered in different regions; ice and long winters in one, snow-meltings and floods in another, tempests of wind in a third; and he has made use of the most accurate calculations available in his time of the conditions represented by the Royal Bridge on the Seine, at Paris, that across the Tiber at Rome, that across the Rhone at Lyons, that across the Garonne at Toulouse, and that across the Thames in London. Those flung over the Tiber have had to withstand, excluding the current century, no fewer than thirty overwhelming inundations and swellings of the river, and it is certainly a remarkable circumstance that any one of them should have been left with one stone standing upon another. The Bridge of Caersau, in Languedoc, though constructed, as its builders thought, exactly on the Roman plan, gave way to the first assault, and even the enormous piles upon which it was reared were rooted out of the depths to which they had been driven. The Emperor Trajan, in building his bridge over the Tiber, would not trust to the bed—artificial or natural, whichever it might have been—of the stream, but excavated another and thence commenced his constructive operations, and the renowned Blendel, at Xaintes, on the Clarente, stipulated for a deep foundation of concrete, as concrete, was understood in those days, before he would put a cubic yard of either timber or masonry into his work. Many of these ideas, no doubt, were not less crude than they were old-fashioned, yet they exemplify how the science and practice of bridge-building have grown up in various parts of the civilized world, and the uncivilized also, since long before a suspension bridge was thought of in Europe, it had been a familiar principle among the wildest tribes inhabiting the jungles of Asia, who found in the flexible and elastic bamboo the materials of such edifices ready to their hands, and who elaborated them with a marvellous instinct as to weight, balance and capacity for resisting the variable temper of the weather and the attacks of floods. It is true that no human precaution can always suffice to prevent danger to such, or similar edifices, from hidden causes. Michael Angelo Buonarotti himself, though he laid the foundations of St. Peter's, at Rome, with every conceivable precaution, did not reckon upon the subterranean percolations down from the summit of the Vatican and Janiculan hills. The great Corderic of Rochefort, also, was thus undermined, and so with the foundations of many ancient bridges; there were rivers under rivers, streams under streams, never taken into account by the architect, yet, nevertheless, fatal, in the long run, to his work. There was a long controversy, at one time, concerning the materials to be employed, stone, marble or timber. Timber, clearly, would not suffice for enterprises of the first magnitude, constituting the prolongations or junctions of imperial highways. The Romans and the Gauls, as a rule, pronounced in favor of the hardest stone, rising above buried forests of oak or pine, while the Italians, generally speaking, declared for marble, at once their favorite and their most familiar product. "A bridge," said Michael Angelo, "ought to be built as though it were intended to be a cathedral; with the same care, of the same materials;" and he only repeated the words used by the unknown architect, a Roman, of the apparently imperishable Pont du Gard, in which the mason and the mathematician would seem to have had an equal share. The bridge of La Guillotiere, on the Rhone, was built on precisely the same system, and is a ruin; but it was not destroyed by time or ordinary wear and tear, it was blown up in time of war; and to its architect was attributed the blame properly due to a company of French sappers and miners, with whom, as they themselves say, "nothing is sacred"—nor to their architects either, in another sense, because there was once a project for bridging the Nile, a river which never yet has known a bridge, in the proper sense of the term. The French, however, during their occupation, conceived the idea, ransacked the entire valley for stone, cast predatory eyes upon the pyramids, and were only deterred from their undertaking, one never dreamed of, even by the most magnificent of the Pharoahs, by the exigencies of war. Had they not discovered a sufficiency of stone, their engineers, it was announced, would fall back upon the bricks, in the supply of which Egypt has never failed. Why not? it was asked. The beautiful structure at Toulouse was originally brick-built from base to parapet, though its elaboration approached that of sculpture. Among other edifices of this class, however, must not be forgotten those which were expressly designed to break the force of torrents and descending masses of ice—solid, yet complicated, arrangements, all traces of which were long ago swept away, but which once were famous in the valleys of the Alps and Pyrenées. In point of fact, since bridges have, in all civilized times, been found essential to the mutual intercourse of populations separated by rivers, it is not surprising that they have equally, in all civilized and artistic times, engaged the utmost ingenuity of mankind, in order that they might be, if possible, at once safe, splendid and commodious.

SOME DIFFICULTIES ENCOUNTERED IN SINKING A SHAFT FOR THE SECOND LAKE TUNNEL AT CHICAGO, ILL.*

By Mr. ELIOT C. CLARKE.

This shaft was sunk in the well of the water-works crib in Lake Michigan, two miles from shore. The writer was assistant engineer in immediate charge of the work, which was carried on in 1873.

One shaft connecting with a five-feet diameter tunnel had previously been built in the crib well, and the new shaft was to be used in building a second and larger tunnel. The water in the well was about thirty-two feet deep, and the tunnel was to be about thirty-five feet below the bottom of the lake at that point. The shaft consisted of a cast-iron cylinder, and no difficulty was experienced in sinking it through the water, and for about thirty feet in good clay. At that depth a vein of sand was met with, which probably extended to the tunnel previously built. A great deal of water came into the shaft from this sand, and it was feared that even if it was possible to pump it, much sand would run into the shaft with the water, and perhaps, by leaving cavities about the first tunnel, cause it to be broken. It was therefore decided to force the water out by use of the plenum process. Air pumps were procured, an air lock put upon the top of the cylinder, the water driven out by air pressure, and the work proceeded under these conditions.

The speaker then described the difficulties attendant on the use of compressed air, especially the many cases of "caisson disease" from which the workmen suffered. The intensity of pressure varied from thirty to thirty-five pounds per square inch. About twenty-five cases of disease occurred. The symptoms consisted of severe pains in one or more of the limbs, sometimes involving the head and trunk. In more than one half of the cases there was present partial or complete paralysis of the parts affected. Two cases of slight paralysis unaccompanied by pain occurred, one of an arm, the other of the optic nerve, rendering the patient blind for half an hour. In several cases the pain was intermittent, and seemed very much like cramp, contorting the limbs affected. The duration of the disease in its acute form was from eight hours to three days. In the more severe attacks discomfort was experienced for several days longer, and swellings of the limbs were sometimes two or more weeks in subsiding. In two cases pain was felt at intervals for three months after apparent recovery. There was no fatal case, and seldom any medical attendance. Local applications of "pain-killing" liniments sometimes afforded slight temporary alleviation. A return under pressure invariably banished all symptoms of the disease; but except in three instances, these reappeared on coming out of the air lock. The length of shift was two hours, and three such shifts in twenty-four hours constituted a day's work. The rate of pay for workmen who entered the cylinder was finally raised to $1 an hour.

By such methods, the shaft was finally sunk to the required depth, its bottom secured, the air lock removed, and an

*A paper before the Boston Society of Civil Engineers.

effort was made to begin the tunnel. At the first attempt, when a very small opening had been made in the side of the shaft, an irruption of soft clay and water occurred, which filled the shaft in a few minutes, and nearly drowned the engineer, superintendent and two miners who were at work in it. It was then discovered that the compressed air, escaping, as it frequently did, under the bottom edge of the cylinder, and working its way up along its sides, had demoralized the clay and afforded free access to the water of the lake.

A great deal of puddled clay was first put around the shaft, and an attempt was then made to pump it out. When, however, the water had been lowered about sixty feet, a second irruption occurred.

More clay in bags was then put about the shaft, the water gradually lowered by pumping, and through more than one hundred holes drilled in the sides of the cylinder, in every direction, round iron rods, seven feet long, were thrust out into the clay. It was hoped that the bags would catch upon these rods and be held. A very heavy sail-cloth jacket was also fitted around the cylinder, and extending on the surface of the ground as far as possible, was covered and weighted down with clay and stones. The water was finally entirely pumped out of the shaft; but shortly afterwards a third irruption occurred, the bags of clay and the sail-cloth disappeared, and the shaft again filled with water.

The air lock was again put on the cylinder and the water forced out by air pressure. Attempts made by the most skilful miners to start the tunnel, and to confine the air by using tongued and grooved ash poling boards with leaded joints, were unsuccessful. More clay was put around the shaft, and a horizontal slot was cut in the cylinder, through which fan-shaped, forged iron bars, two inches thick and seven feet long, were driven, forming with each other a solid iron roof above where the tunnel was to be. The demoralized clay extended three feet from the shaft, and the iron roof penetrated four feet into solid clay. Under the protection of this roof the tunnel was at last started, and no more difficulties were encountered. Transferring the line from above ground down to the tunnel required great care in this case. The line was obtained from sights two miles distant on the shore, and was transferred from the top of the crib to the bottom of the shaft by plumb-lines one hundred feet long. As the shaft was not vertical the base obtained at its bottom was only four feet long. From this short base the line was carried about fifty feet southward, where an angle of about ninety degrees was turned, and the line prolonged westward to meet the tunnel already begun from the shore. The error in alignment when the headings met was found to be about eighteen inches.

NEW IDEAS ON HYDRAULICS;

CHIEFLY RELATING TO PIPES, CANALS, AND RIVERS, WITH A THEORY OF THE ESTIMATION OF MOLECULAR RESISTANCES.

By P. BOILEAU.

From Abstracts published by the Institution of Civil Engineers.

The general motion in a stream is first discussed, and the law announced that where filaments have different velocities, the slower moving deviate towards the quicker. Other external motions, such as eddies and induced currents are then discussed. The periodicity of the motion of translation in streams is pointed out. In a stream moving in contact with solid surfaces, there is a region comparatively limited in extent, near the surfaces, where the internal movements are violent. This is termed the troubled zone. The difference of the law of flow in small and large pipes is ascribed to the large proportion of the section occupied by the troubled zone when the pipe is very small.

The author then shows that a stream in uniform regime may be divided into layers, bounded by surfaces traced out by lines parallel to direction of translatory motion, which have curves of equal velocity for directrices. Each layer consists of molecules having the same mean velocity of translation. The resistance to the motion of the stream is shown to be due to the components parallel to the stream of the reactions due to the roughnesses of the sides; to the shearing of the fluid contained in capillary pores of the surface on which the fluid moves; and to the internal movements in the stream. After some discussion of a general theory of these resistances, the author proceeds to examine the law of distribution of velocities in the section of a stream. He first points out that, in many experiments hitherto made, the necessary conditions for obtaining true results have not been fulfilled. Experiments of his own in 1845 showed that the filament of greatest velocity (the principal filament) divides the vertical longitudinal section of the stream into two parts, in which the distribution of velocity is not exactly the same. Below the principal filament a formula of the form $v = A - Bz^2$, where z is the depth from surface, exactly expressed the law of variation of velocity. Results selected from the Mississippi experiments, and from those of Bazin, confirm the law for extremely different cases. A general expression is then found, applicable to all streams, for the position of the principal filament. In vertical sections other than that passing through the principal filament, the filament of greatest velocity is lower than the principal filament. An expression is then found for the distribution of velocities in a horizontal section, and this is compared with the selected experiments.

The flow of water in pipes is then investigated, some of Darcy's experiments being used to test the results. Taking from Darcy the mean velocities U, and the maximum velocities V, the remarkable result is obtained that

$$\gamma = \frac{V - U}{\sqrt{i}}$$

is constant for each pipe, i being the loss of fall per unit length. Darcy's results being insufficient for the purely empirical determination of the law of distribution of velocity in a pipe, the author seeks a rational basis for such a law. This leads to the adoption of the expression

$$\gamma = a + b R^{\frac{5}{2}},$$

where a and b are constants depending on the roughness of the sides of the pipe. This enables him to obtain the following law for the distribution of velocity:

$$V - v = \frac{7}{4} \gamma \sqrt{i} \left(\frac{y}{R}\right)^{\frac{3}{2}},$$

where V is the maximum velocity, R the radius, and v the velocity at radius y. From this, formulæ for the mean velocity, velocity in contact with sides and discharge are deduced. It is one consequence of the formula above, that the velocity at a radius 0.6887 R is the mean velocity. Darcy had placed the mean velocity at almost exactly the same point.

The law of distribution of velocity in pipes is then compared with that independently found for streams. It is shown that the former is a particular case of the latter.

The external resistances and internal actions which give rise to the variation of velocity in a stream are then examined, and the defectiveness of the old notions of friction on surfaces, on which Prony's formula is based, is pointed out. For the intensity φ of the resistance to the relative motion of two consecutive layers, at radius y, in a pipe of radius R, the value obtained by the author is,

$$\varphi = \frac{32}{441} \delta \frac{R^3}{\gamma^2} \left(\frac{dv}{dy}\right)^2,$$

δ being the density of the liquid. This expression differs in form from those proposed by Navier, Darcy, Boussinesq, and other hydraulicians, not only as to the influence of the diameter, but also in the variable factor for the same pipe. For canals and rivers the corresponding expression is

$$\varphi = \frac{1}{4} \delta \frac{H^4}{\mu^2} \frac{r_1}{z_2} \left(\frac{dv}{dz}\right)^2,$$

where r_1 is hydraulic mean radius of the liquid cylinder considered, z its depth from the surface, H the whole depth of stream, and μ a constant depending on the roughness and form of channel.

It remains next to estimate the intermolecular work which gives rise to the resistance to relative motion of the layers. In streams the molecules are displaced transversely from slower to quicker parts, their place being taken by other molecules coming from above. The ratio of the intermolecular work to the whole work of gravity on the stream is found to be

$$\frac{\zeta}{i} = 1 - \frac{w}{U},$$

where ζ is the fall expended in overcoming intermolecular resistances, i the whole fall lost; w is the velocity in contact with the sides, and U the mean velocity of the stream.

Deducting the intermolecular work, the remainder of the resistance to the motion of the stream is due to the action of the surfaces bounding it; and this alone is, strictly speaking, friction. The amount of the intermolecular and frictional resistances in Darcy's experiments on smooth and incrusted pipes is then calculated and discussed.

ON THE NEW COPYING PROCESS.

From "Nature."

A very elegant process has recently been introduced into this country for copying and multiplying letters and documents. It is known by various names, according to the etymological skill of the makers. One calls it a "hektograph," another less pardonably calls it the "centograph," while yet another, to bridge the gap between ancient Greek and modern English, styles it the "printograph." But whether it is introduced by these names, or the polygraph, the compo-lithograph, or the velocograph, the principle is the same; though the details are slightly varied in each case. A slab of gelatinous material in a shallow tin tray forms the type. The letter is written with a special ink on any kind of paper, and when dry is placed face downwards upon the jelly, and allowed to remain a minute or more. On removal it is found that the greater part of the ink has been left behind on the jelly. It is only necessary to place pieces of paper on the latter, and on their removal they are found to be perfect fac similes of the original copy. The number of copies obtainable varies with the ink, the most potent being aniline violet, such as Poirrier's. With this a hundred copies may be produced. Others, such as Bleu de Lyon, Bismarck brown, or Roseine,* yield forty to fifty. It was with a view to determine the principles which govern this beautiful process, that I made an examination of the subject. The slab consists of gelatin and glycerine, with carbolic or salicylic acid to prevent fungoid growth, and in the "chromograph" a quantity of barium sulphate is added, which gives the slab a white, enamel-like appearance.

If a hot, strong solution of gelatin in water be prepared,* and then a certain quantity of glycerine stirred in, the whole mass will become solid in cooling. This might at first sight appear to be a solution of gelatin in water *and* glycerine; but such is not the case, the gelatin being quite insoluble in glycerine. When the aqueous solution solidifies, the gelatin still retains the water, but the large quantity of glycerine being dispersed through the mass, makes the whole into what is practically *a very fine gelatin sponge containing glycerine in its pores.*

The moisture-loving nature of the glycerine prevents the "sponge" from getting dry, while the insolubility of the gelatin in the glycerine prevents it becoming liquid. When the copy is placed on the jelly, the glycerine comes out to meet the ink, for which it has an intense liking. All the suitable inks are freely soluble in glycerine. Some, too, contain acetic acid either in the free state or in combination with bases as in rosaniline

*A very potent and easily prepared ink which will yield a hundred copies, may be made by dissolving rosaniline in a cold-saturated solution of oxalic acid. It must be allowed to dry spontaneously.

†4 oz. gelatin dissolved in 6 oz. water, and 20 oz. glycerine, sp. gr. 1.26, previously warmed, stirred in. Any air bubbles in the gelatin are removed before the addition of the glycerine. A cheaper compound which answers equally well, but is rather darker, consists of Scotch glue, 6 oz., water 8 oz., glycerine 20 oz. These quantities make a slab 10×13×¼.

acetate. The acetic acid exerts a solvent action on the gelatin, so that it will be found that after taking off some impressions with an acetic acid ink, as the "multiplex," the jelly will be etched wherever the ink has come into contact with it. As long as any of the ink remains on the jelly, the glycerine will come out of the pores to keep it moist, but when the whole of the ink has been removed the flow of glycerine ceases, and the parts become quite dry. If the ink is not entirely removed by taking a sufficient number of impressions, and the jelly left, after a lapse of twenty-four hours the remaining ink will be absorbed by the jelly. It is necessary, therefore, that the copies should be taken off as soon as possible, so as to avoid the defect caused by the spreading of the ink.

Most of the makers suggest, that directly the slab is done with, the type should be washed off. The hektograph and most others require that the water should be warm, but the finely divided barium sulphate in the chromograph, renders the surface less tenacious, and the impression may be removed with cold water.

Where practicable, it is better in all cases to leave the slab for twenty-four hours, when the old impression will be quite absorbed, and not interfere with a new one.

This gelatin copying process has been received with so much favor by the public, that it shows there is a great want for some rapid means of getting a limited number of copies of letters, &c.; and seeing that any number of colors may be used in the original drawing, Mr. Norman Lockyer has suggested that it would be of much use in laboratories, for the multiplication of original sketches of biological specimens, and even for spectra charts, and so save much of the time spent in making duplicate copies. The gelatin slab cannot be said to be perfect, as it is liable to be affected by atmospheric changes; but, bearing in mind the fact that the whole is simply a sponge filled with a compound capable of liquefying certain inks, it is reasonable to hope and expect that chromography is only the pioneer of a process, which shall possess all its advantages and none of its defects.

REPORTS OF ENGINEERING SOCIETIES.

Engineers' Club of Philadelphia.—This Society held its regular meeting on April 3d, at which Mr. Rudolph Hering, C. E., exhibited the original drawings of the United States Coast Survey map of the Delaware River from Bridesburg to Fort Mifflin; Mr. A. E. Lehman, M. E., presented a lithographic topographical map of the middle section of the South Mountain range, in Pennsylvania; Mr. Howard Murphy, C. E, submitted a well-preserved volume of Robert Fulton's "Treatise on Canals;" Mr. A. R. Roberts, C. E., described a model of a self-adjusting crossing frog, made for the Philadelphia & Reading Railroad Company, noticing the objections to the ordinary frog, and the manner in which they had been overcome; Mr. Arthur W. Sheafer, C. E., exhibited a diagram, prepared by P. W. Sheafer, Esq., of Pottsville, showing the progress of the anthracite coal trade, and the relation of the amount of coal shipped to market to the coal area. For every ton mined three tons are wasted.

American Society of Civil Engineers.—The last two issues of the Transactions are filled with discussion upon the subject of "Inter-oceanic Canal Projects," participated in by Julius W. Adams, Ashbel Welch, Edward P. North, Walton W. Evans, John C. Campbell, Charles A. Sweet, Frederick M. Kelley, and many others.

It may be safely assumed that the January and February numbers present the most concise statement of this great question that has yet appeared in print.

Paper No. 189, in the March number, contains:—The Engineering Problems involved in the proposed improvement of the Erie Canal by increasing the depth one foot, by E. Sweet, Jr.

The American Society of Mechanical Engineers.—The meeting for the organization of this Society was held at the Stevens Institute on the 7th of April. The following rules were recommended at the preliminary meeting:

MEMBERSHIP.

Art. 2. The Society shall consist of members, honorary members, associates and juniors.

Art. 3. Members and honorary members shall be professional Mechanical, Civil, Military and Mining Engineers and Architects.

Art. 4. To be eligible as a *member*, the candidate must have been in the practice of his profession for at least seven years, not merely as a skillful workman, but as qualified to design and execute engineering work, and he must have been in responsible charge of work in his branch of engineering.

Art. 5. *Honorary members*, not exceeding twenty-five in number, may be elected. They must be persons of acknowledged professional eminence, who have virtually retired from practice.

Art. 6. To be eligible as an *associate*, the candidate must have such a scientific or commercial connection with applied science, as will qualify him to co-operate with engineers in the advancement of professional knowledge.

ART. 7. To be eligible as a *junior*, the candidate must have been in the practice of engineering for at least two years, or he must be a graduate of an engineering school. [The term "junior" applies to the professional experience, and not to the age of the candidate. Juniors may become eligible to membership.]

ART. 8. All members and associates shall be equally entitled to the privileges of membership, provided that honorary members who are not also members or associates, and juniors, shall not be entitled to vote, nor to be members of the Council.

FEES AND DUES.

ART. 18. The initiation fee of members and associates shall be $15, and their annual dues shall be $10 per year, payable in advance at the annual meeting, *provided* that persons elected at the meeting following the annual meeting shall pay $8, and persons elected at the meeting preceding the annual meeting shall pay $4, as dues for the current year. The initiation fee of juniors shall be $10, and their annual dues shall be $5 per year, payable in advance. Any member or associate may become, by the payment of $150 at any one time, a life member or associate, and shall not be liable thereafter to annual dues.

Prof. Robt. H. Thurston was elected President.

IRON AND STEEL NOTES.

THE DEPHOSPHORIZATION OF IRON.—At the Cleveland Institution of Engineers at Middlesborough, Mr. J. E. Stead (Pattinson and Stead), analytical chemist, read a paper on the dephosphorization of iron. He said that he had made several experiments to ascertain the effect of manganese upon phosphate of lime, and also upon phosphate of manganese. Into the bottom of a small basic-lined crucible he placed 1½ grammes of phosphate of manganese, containing 71½ per cent. of manganese. In a second crucible a similar quantity of phosphate of lime was placed, and on the top of it the same quantity of ferro-manganese, which was carefully covered over with more phosphate of lime. Into a third crucible he also placed phosphate of lime, and over it 5 grammes of carburretted iron, containing little or no phosphorus. All these crucibles were placed side by side in a large plumbago crucible, imbedded firmly in powdered basic bricks, and after the covers were securely placed, they were covered with about one inch more of powdered lime. The lid was then placed upon the crucible, which was impounded into a furnace and heated to whiteness for about an hour. It was then removed, and the fused metallic buttons taken out and subjected to analysis. The button from the crucible which held phosphate of manganese contained 67.6 per cent. of manganese, and an increase of 1 per cent. of phosphorus. That from the crucible containing phosphate of lime had increased a little over 1 per cent., the manganese being respectively 67.6 and 68.6 per cent. The phosphorus in the decarbonized iron, which was treated in a similar manner to ferro-manganese for comparison, had not increased above one tenth or 1 per cent. In another experiment, where the crucible was kept in the furnace for a greater length of time, it was shown that nearly 5 per cent. of phosphorus had been gained by the metallic button of ferro-manganese. Judging from these results he thought it was very clear that manganese not only powerfully acted upon the phosphoric acid contained in phosphate of manganese, but it also had a great reducing effect upon the phosphoric acid contained in phosphate of lime. He thought that those results went to prove that it was manganese which reduced phosphoric acid from the cinder in the Bessemer converter. The matter deserved more investigation, and what between the results obtained by Mons. Pourcel and himself (Mr. Stead) he thought that before long he would be able to give a most satisfactory explanation of this phenomenon. The fact that manganese reduced its own phosphate showed them that the metal, subjected to the dephosphorizing process in which it was the object to remove the phosphorus before the elimination of the carbon, told them directly that it must be as free as possible from that element, for as long as mangenese existed in the metal it would have a tendency to reduce any phosphate of manganese or lime produced during the early stages of the blow. Attention had been drawn to the great desirability of supersaturating the scoria with lime, in order that the life of the linings might be prolonged. Great advantage had, it was stated, been obtained on the Continent by the use of iron containing little or no silicon, and an increased proportion of phosphorus. Several methods had been proposed to bring such iron to the converter. The first was that which was being practically carried out at Hörde, where white iron containing about ½ per cent. of silicon was used, together with a sufficient quantity of phosphide of iron, made specially for the purpose of giving the necessary amount of heat in blowing. The second was that which consisted in blowing out the silicon from the metal in a ganister-lined converter, running off the slag and then transferring the desiliconized iron at an increased temperature to the converter lined with basic bricks. This had been carried out at Messrs. Bolckow, Vaughan & Co.'s steel works at Eston. The third method was that described by Mr. Warner. in which he proposed to smelt with the Cleveland iron ore a sufficient quantity of the basic slag or phosphoretic material to give an increased proportion of phosphorus in the iron, and to desiliconize this iron with a mixture of soda ash and limestone, which he (Mr. Stead) confessed was the most rapid and complete process of refining that had ever yet been before the public. The desiliconized iron, after leaving the desiliconized converter, was taken to the Bessemer vessel, and there blown in the usual way. There were other methods of purification, one of which was that of Bacon and Thomas, in which oxide of iron and limestone was charged together with pig iron in a cupola furnace, and the whole were melted down together. This method effected a more or less complete removal of silicon, which depended altogether upon the quantity of oxide of iron charged. The question as to which of those processes would ultimately be found most practicable and least costly was one which experience only could answer. Messrs. Krupp have patented a slight modification of this process, and, if it was thoroughly successful, the refined iron would be very valuable for puddling processes, but for the Bessemer converter would be almost useless. With reference to an important point—the disposal and utilization of basic slag—Mr. Stead said that although it contained between 20 and 40 per cent. of phosphate of lime, the presence of from 5 to 15 per cent. of combined iron made manure manufacturers think that it would not answer to make superphosphate of lime from it. It seemed to him that as a manure it would be most valuable in a raw state, after grinding to a fine powder. The cinder, especially that which was least silicious, was valunble as a means of increasing the proportion of phosphorus in pig iron, where the amount naturally was not high enough to give the necessary amount of heat in the converter, and also as a flux for blast-furnaces. Excepting the phosphoric acid, slag of such a nature was more valuable than an equal weight of limestone, for the metallic shots of combined iron would be obtained, and the manganese would probably have an influence in removing sulphur from the metal in the blast-furnace, or perhaps, to state the matter more correctly, would prevent it from entering into combination with the iron.

Mr. Thomas, after complimenting Mr. Stead on the ability of his paper, pointed out what had been done on the Continent with reference to the desphosphorization of iron. Perhaps the most important result that had been attained during the past six months was the complete demonstration that had been afforded of the truth of the propositions advanced some eighteen months ago, by which, in the ordinary Bessemer process, white pig could be advantageously substituted for grey Bessemer pig. The advantages of this substitution were over cold. As they all knew, a furnace working on white produced far more, and with a smaller expenditure of fuel, than when working on grey iron. There were many furnaces considerably smaller than the larger Cleveland type, which were to-day producing weekly considerably over 700 tons of white pig. Then, the waste in converting the white pig is very much smaller than when working on grey silicious iron. He was glad to say that they had within the past few weeks almost surmounted the gathering at the throat of the converter, which had proved so serious an inconvenience at Eston and elsewhere, by a very simple device. So far they had not succeeded in obtaining rapid working, but they were rapidly pulling up on the Continent. Their production from four five-ton vessels was from thirty to thirty-five thousand tons, which was considered fair enough, and to that rate they had nearly attained. But Mr. Richards and the big mill at Eston were not so easily satisfied. They were all satisfied to emulate American and the best English practice, and to do that modifications of the existing plant were necessary which they had hitherto not thought it expedient to insist on, but which were indispensable for quick working. He might say, however, that they were now spending some money to enable a large output to be produced. Five new Bessemer works were being built expressly for this process at a cost of five or six million francs.

In answer to a question which had been put to him as to when they would see the new steel in the markét ln large quantities, he said that the five new works he had just referred to would have a capacity of over a quarter of a million tons per year if required, and nine or ten existing Bessemer works had already decided on adopting the process, or were already working it It seemed probable that steel from phosphoric pig-iron would be speedily seen in large quantities. At present the production was small—probably not more than fourteen or fifteen hundred tons per week; and he had no hesitation in saying that when the alterations now being carried out at the works already in operation were completed, that production would be doubled. As to the prospects of the steel industry in Cleveland, he would venture no opinion, as it was a question they were better qualified to decide for themselves. He might, however, mention the fact that Cleveland pig-iron had been purchased in Middlesborough, taken to the Continent, and there converted into steel, and sold in successful competition with English steel for the American market, at a very satisfactory profit. After a few further remarks, he said he was glad of the opportunity of expressing the obligation Mr. Gilchrist and himself were under to many gentlemen in the Cleveland district who had so materially assisted them in bringing the dephosphorizing question to its present condition, and he wished specially to mention Mr. Winsor Richards, manager of Messrs. Bolckow, Vaughan & Co., and Mr. J. E. Stead, of the firm of Pattinson & Stead, analytical chemists, the latter of whom, he discovered long ago, was always ready to act as an impartial and most accurate critic of the crude hypotheses which constantly occurred to them, as affording possible clues to the solution of practical difficulties, and they had never failed to avail themselves of such suggestions.—*Iron*.

RAILWAY NOTES.

It is proposed to construct a railway from Hambantota to Uva, Ceylon. The present means of transport of the produce of Uva, a large and populous district, is entirely by bullock carts *via* Ratnapura to Colombo; *via* Newera Elliya to Gampola; and a small percentage finds an outlet by the Batticaloa road. The great bulk of the traffic passes over the Ratnapura road to Colombo; which is 112 miles from Haputale, 136 from Badulla, and 170 from Madulsima. The cost of transport is excessively expensive on account of the great distance from the seaboard; from the losses that have to be sustained by planters in having their coffee stolen from the carts on the road to Colombo; from the deterioration of the crop by being so long on the road; from the uncertainty of transport on account of the mortality of bullocks in unhealthy years, and from the stoppage of traffic by the land slips that are constantly occurring at Halpé. The Government of Ceylon have surveyed a line of railway from Navalapitiya—the present terminus of the existing railway—*via* Nanoo Oya and Happutale Pass into Badulla. It is expected that tenders for the construction of the first section will be invited within a month or two; but as the present portion of the line from Nanoo and Badulla will be very heavy, it is, according to a circular by Mr. H. K. Rutherford, not to be proceeded with.

Mr. W. T. Gunson's improved system of tramways, referred to in a previous number, was again discussed by the members of the Manchester Scientific and Mechanical Society at their meeting on Friday. The president—Mr. J. Bowes—thought that, although the system was a step in the right direction, there were yet some practical defects which would militate against its adoption. One objection would be the amount of skilled labor which would be required in laying, and he thought the smooth surface of the sleepers would be a disadvantage. Mr. A. Jacobs, Borough Engineer, Salford, also thought the sleepers would work smooth, but he chiefly criticised Mr. Gunson's estimates of cost, which, in his opinion, were considerably below the mark. Mr. McLeod thought a difficulty would be found in the expansion and contraction of the rails, whilst Mr. Heys thought this would be counteracted by the other materials, and with regard to the sleepers, added that he did not consider a smooth surface necessarily a slippery one. Mr. Savage, Deputy Superintendent of the Manchester Fire Brigade, thought that the oscillation which he had found, caused to the fire engines in riding through the streets by the present tramway, would be obviated by Mr. Gunson's system. Mr. Gunson having replied upon the discussion, in which he said no serious objections had been raised to his system, and having defended the estimates laid down, the president closed the proceedings by observing that four or five different systems of tramways had already been submitted to the society, but he thought they would agree with him that Mr. Gunson's was the best they had yet the opportunity of discussing.

ENGINEERING STRUCTURES.

The Tay Bridge.—At a meeting of the Institution of Engineers and Ship-Builders in Scotland, Mr. St. John Vincent Day gave a detailed account of observations made by himself and a number of members of the institution of the remains of the Tay Bridge, in which he showed that the bridge was in some instances not only defective in design but inferior in workmanship. He explained that the castings showed in several places that they had been poured too cold, were irregular in thickness and in some cases castings were found with blown holes which had been filled with lead. Evidently, then, he said, some persons engaged in he work must have been cognizant during the whole life of the bridge of at least one vital element of its insecurity, for the lead evidently was designedly put there. He likewise pointed out that the flanges of the piers had not been properly brought together, and in one case the inspecting party had found a space of 14 inches where the concrete had spread out between the flanges. A headless bolt, which had been painted over, was also found. These facts spoke for themselves but too terribly to the members of the Institute of Engineers.

Mr. James G. Fairweather, Edinburgh, said that in common with every engineer in the country, he deeply sympathized with Sir Thomas Bouch in his present position. He was extremely desirous, however, that the true cause of this unparalleled engineering disaster should be as satisfactorily brought to light as the cause of the explosion of the 38-ton gun on board H.M.S. *Thunderer.* One of the principal defects of the bridge, he held, was the want of breadth of base. The piers were almost parallel, and his opinion was that they should have been spread out—even in Sir Thomas Bouch's other design he had them thus placed. His belief was that the bridge had been blown over, just in consequence of the want of breadth of the piers. The bridge would have fallen on the 28th December, even although the train had not crossed it that night; but at the same time he believed that the train assisted considerably the other forces then acting. Then the insufficiency of the length of the holding bolts was but too plainly seen in the case of two or three of the piers, and it certainly would seem absurd, to say the least of it, to have holding-down bolts capable of lifting, before breaking, say about 200 tons, and that they were, in some cases at least, only attached to two courses of ashlar 15 inches thick, weighing, say, about six or seven tons. That these columns should have been cast on their side seemed monstrous, and he should say that any engineer who omitted to specify that the columns were to be cast on end would be deserving of censure.

Mr. Page said that Mr. Day's report of what the party of Glasgow engineers who visited the bridge saw was very faithful. He would just add that he never saw such shamefully bad work. The masonry was very bad indeed, and the ironwork was very bad also. Indeed, he never saw such bad in his life.

Mr. John Thomson said along with the others he had visited the bridge on the previous day, and he thought there was much about the structure and the circumstances of its fall which the Institution might well consider. The ties were entirely the weak part of the structure. They were mere ribbons, and it was perfectly clear that the whole bridge had collapsed like a parallel ruler. He thought the bridge had the elements of destruction in itself, and that it was a mere question of time how long it would stand. Many of the bolts they saw had old cracks in them. A great deal had been said about the use of cast iron and the castings, but he did not think the destruction of the bridge rested with the castings. His opinion was, that had the columns—they were too small—been properly stayed with stiffening stays, and not been merely tied with mere ribbons, the ca

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tastrophe would not have occurred. It ought to have been so stiff that it should have turned over itself without collapsing. It was evident that the snugs broke off, and the columns just collapsed. It was a serious question whether or not it was possible to do anything with the rest of the bridge—whether it would have to be taken down, or the portions at present standing made use of in the reconstruction. His opinion was that the remaining parts could be so strained up by diagonal struts as would make it of sufficient rigidity to sustain the work it had to do without taking it down. The curve that was made at the north end of the bridge was, he considered, a fatal defect in itself, and he thought that it was unfortunate that there should have been such a gradient at this particular portion. The trains ran over that part at a very high rate of speed, and an engineer friend in Dundee, who had often timed the trains, told him that at the high girders the trains ran at the rate of from 40 to 43 miles per hour. That, they knew, was very much more than the authorized rate. In any future reconstruction of the bridge it would be necessary that there should be some very strong stiffening studs in a direct line with the force on the south side.

Mr. Gale said he was one of those who thought that, however strongly the piers had been braced together, the bridge would have been blown over on the occasion that it was. It could very easily be shown that a wind pressure of 35 lbs. on the square foot would have been sufficient to have thrown one of the long girders into the sea, quite irrespective of the manner in which the pier was braced. If the pier had been stronger in the bracing the result would simply have been that the girder would have been thrown a little further from the piers, but here the bridge dropped right down at the root of the piers, just as a chimney stalk fell when blown over by the wind. There was, however, no bracing that would have preserved the bridge from ultimate destruction.

ORDNANCE AND NAVAL.

Clyde Shipbuilding in 1879.—The returns of the tonnage of vessels launched on the Clyde during the year drawing to a close show a falling off compared with 1878, of 49,150 tons, but compared with 1877 an increase of 3,493 tons. This state of matters is sufficiently accounted for by the great depression which prevailed during the first ten months of the year. During the last two months the prospects have greatly brightened, and at the present time there is a large amount of work on hand which will materially affect next year's figures. The total number of vessels launched on the river during the year was 170 of an aggregate tonnage of 173,438 tons, as compared with 236 vessels and 222,353 tons in 1878. One feature of the work of the year has been the number of steel-built vessels launched, which have reached an aggregate of 18,808 tons. Messrs. Denney and Brothers, of Dumbarton, have built no fewer than ten of these ships. These included a steamer of 4000 tons for Messrs. J. and A. Allan's Transatlantic service, and two steamers for the Union Steamship Company of Australia of 1728 and 1653 respectively. Messrs. John Elder & Co. built for Messrs. Donald Currie and Co.'s Cape Mail service a steel vessel of 3000 tons; and Messrs. R. Napier and Sons, Govan, two steel steamers of 2520 tons each for the Pacific Steam Navigation Company. Several important additions were made during the year to the great ocean-carrying companies. The chief of these were the *Orient*, 5386 tons, for the Orient Steam Navigation Company, and the *Arizona*, 5,147 tons, Guion Line. Both these vessels were built by Messrs John Elder & Co., Govan. During the last two years several vessels of large dimensions have been constructed on the Clyde, while other monster ships are either in the hands of builders or are being planned by naval architects. Competition amongst the great line of ocean steamers has of late become extensively keen, and there is an evident desire on the part of the ship owners to outstrip each other in the dimensions of their vessels. Whatever qualifications must be possessed by the ocean steamships of the immediate future, it is interesting to note that great size is likely to be one of their characteristics. A few details regarding the large vessels recently built, and for the sake of comparison, the largest ship afloat (the *Great Eastern*), will be of interest at the present time. Last year Messrs. J. and G. Thomson, Clyde Bank, built the *Gallia*, a Cunard Liner, of the following dimensions:—Length over all, 450 feet; breadth, 44 feet; depth, 36 feet. The tonnage of the *Gallia* is 5200 tons. During the present year Messrs. John Elder & Co., Govan, completed two large, powerful steamers, each over 5000 tons. The *Arizona*, built by Messrs. Elder & Co., for the Guion line, is 465 feet long, 46 feet broad, and 37 feet in depth, her tonnage being 5300 tons. She is capable of carrying a dead weight of cargo, exclusive of 1200 tons of coal in the bunkers, of 2600 tons. The second large vessel built this year by Messrs. Elder & Co. was the *Orient*, a steamer of the following dimensions: —Length, 460 feet; breadth, 46 feet 6 inches; depth, 37 feet 8 inches; tonnage, 5386 tons. The *Orient*, which was the largest vessel ever lanched on the Clyde, has a displacement at load draught of over 9500 tons. But the Cunard Company are having built for them by Messrs. J. and G. Thomson, Clyde Bank, a steamer larger than either the *Arizona* or the *Orient*, and exceeded in size by the *Great Eastern* only. The new vessel will be 7500 tons and 10,000 horse-power, her dimensions being 500 feet in length, 50 feet in breadth, and 41 in depth. No sooner had the Cunard Company announced their intention to build a vessel second in point of size to the *Great Eastern* only than the Inman Company determined to add to their Transatlantic service a steamship of even still larger dimensions. The contract for the new Inman Liner has not yet been closed, but we understand that it has been resolved to have it built at Barrow, and that it is to be an 8000-tonner. The length of the *Great Eastern* on load water-line is 680 feet, breadth extreme 82 feet 6 inches, and her depth at the side is 58 feet. Her tonnage, according to builder's measurement, is

22,627 tons; her register tonnage, including engine space, is 18,914 tons; and her register tonnage excluding engine space is 13,343 tons. She has stowage for cargo to the extent of 6000 tons, and the capacity in her coal bunkers 10,000 tons Her draught of water light is 15 feet, and her water draught loaded is 30 feet. The displacement of the vessel when light is 11,844 tons, and her displacement loaded is 27,384 tons. She has accommodation for 800 first-class, 2000 second-class and 1200 third-class passengers, but if required for troops alone she could carry 10,000 men. It will thus be seen that the *Great Eastern* is in point of size considerably ahead of anything yet ventured by ship owners, and though there is an evident desire to increase the size of the great acean steamers, the position of Mr Scott Russell's ship as the largest afloat is not likely to be disputed.

CONVERSION OF A WOOLWICH PATTERN-GUN. One of the Woolwich pattern guns converted into a breech-loader for experiment has been conveyed to Shoeburyness for long-range practice. The breech apparatus is on the screw principle, adopted for the breech-loaders now in course of manufacture. It is also proposed to send to Shoeburyness two other converted breech-loaders—one a 40-pounder Armstrong with the trunnions turned so as to place the wedge at the side instead of the top of the piece to allow of its being easily drawn out, and the other a 31-pounder cast iron gun altered in imitation of the Krupp system. These guns have all been tried at Woolwich, and the superiority displayed by the first-named has induced the Ordnance Select Committee to recommend its adoption as the pattern of the new service weapons.

THE "DUILIO."—The Italian monster iron-clad, *Duilio*, has just been put in commission. She represents 22,000,000 francs, and the Italian navy waits the experiment of her performances for its definite systematization. She is now at Spezia. Her displacement is 11,500 tons; nominal horsepower, 7,500. All heavy work aboard, as steering, regulating ventilators, removal of cinders, weighing anchor, is done by steam. There are thirty-three special engines. She carries four 100-ton guns, worked by special and, in part, newly-invented machinery; also twelve smaller guns and four mitrailleuses. A broadside of her four great guns throws 8,000 lb. weight of metal, consumes 2,000 lbs. of powder, and, comprising projectiles, costs 4,000 fr. At each broadside a force is developed sufficient to raise 48,000 tons to the height of 1 meter. She is expected to attain a speed of 12½ knots, and doing so will consume 15,000 lbs. of coal an hour. She carries a Thorneycroft torpedo boat, 22 meters long, which has attained a speed of 21 knots. She starts on her trial trips immediately.

BOOK NOTICES.

SEWERS AND DRAINS FOR POPULOUS DISTRICTS. By JULIUS W. ADAMS, C E., New York: D. Van Nostrand. Price $2 50.

The name of the author of the above work is a sufficient guarantee for its value. Mr. Adams holds so high a place among American engineers, and has for so many years been an acknowledged leader in the profession, that the importance of anything from his pen is sure to be recognized. It is not often that our best engineers can be induced to record the results of their practice. This is much to be regretted, as the life-long experience of these men would be a precious heirloom to the rising race of engineers. The market is flooded with volumes written by men of no experience except in making books, many of them couched in language utterly unintelligible to any except professional mathematicians, to read which is like threshing a bushel of chaff to find a single grain of wheat; while the works of real practical value, which are found thumbed and worn by use in engineers' offices, are so few that they may be counted on the fingers. Yet in their works our engineers have stored up an immense amount of the most valuable instruction, exactly adapted to the use of the younger members of the profession.

The work above referred to adds a volume to the list of books which working engineers will be sure to appreciate. Mr. Adams having designed, with great care, the sewerage system for the city of Brooklyn, embracing an area of some twenty square miles, which, after twenty years of service, has shown no defect in the principle adopted, can hardly fail to give us valuable information. Indeed, he would have done a great service if he had simply described the sewerage works of Brooklyn. But he has done more. He has put the whole subject in a systematic and practical form, under the several heads—Physical Outline of the District, Rainfall, Water Supply, Disposal of Sewage, Preparation of Plans. Materials Used in Construction of Sewers, Foundations, Appendages to Sewers, Street Basins, Tide Valves, Storm Sewers, Intercepting Sewers, Ventilation of Sewers and House Drainage.

The work is full of good sound practical information, and is sure to be of great service to the profession. GEORGE L. VOSE.

SANITARY ENGINEERING. Second Edition. By WILLIAM CAIN, C. E., Member of the North Carolina Board of Health, Raleigh, N. C., 1880.

This very interesting work is issued by the North Carolina Board of Health, and commences with general remarks upon "Death Rates lowered by Sanitary Works," and references are made to Latham's "Sanitary Engineering," and tables given, showing a decrease of death rates owing to proper sewerage. The rate of St. Louis, Mo., from 1867 (when the Board of Health was established) to 1877, was actually decreased, although the population had doubled in that decade. Prof. Cain claims that cleanliness of cities is the principal cause of lessened rates, and treats of the necessity of proper sewerage systems, of the free use of water, of methods for ventilating residences, of the drainage of soils, and of the pernicious influence proceeding from absence of sub-soil drainage. In rural residences he illustrates the disastrous effects of arranging sink spouts and noxious collections so that wells will become contaminated by the poisonous filterings. The work gives full and clear directions for remedying the evils spoken of.

The book is in pamphlet form and contains nearly one hundred pages.—*Eng. News.*

ANALYTICAL CHEMISTRY. By W. DITTMAR. London and Edinburgh: W. & R. Chambers. For sale by D. Van Nostrand. Price, 60 cts.

This petite volume is a neat compendium of laboratory analysis adapted to the needs, more particularly of, medical students. The determination of sugar and urea being dwelt upon at considerable length and with satisfactory clearness.

THE PRINCIPLES OF GRAPHIC STATICS. By GEO. SYDENHAM CLARKE. London: E. & F. N. Spon. For sale by D. Van Nostrand. Price, $5.50

The special feature of this work, which serves to distinguish it from other English treatises on this subject, lies in the treatment of the problems relating to the moment of inertia and moment of resistance.

The book is a well printed quarto, with excellent diagrams.

CALCULATOR OF MEASUREMENT OF PACKAGES BY FRACTIONS OF AN INCH. In two volumes. By MANEKJI KAVASJI TADIVALA, Shroff. Bombay: Printed at the Caxton Steam Printing Press. London: Simpkin, Marshall & Co. For sale by D. Van Nostrand.

Here we have before us a work by a native of India, which bears on the face of it evidenee of its being the result of great mental labor and application for a very considerable length of time. Nothing could be more laudable and worthy of encouragement than the compiler's object, which was to produce a book that should be worthy of being adopted as a standard of metage between shipowners and consignees in estimating the amount of freight on measurement goods, in order to prevent disputes.

Hitherto it appears to have been the custom in calculating the measurement of bales, boxes, hogsheads, and other packages of what is termed light goods for freight, to offset the fractions of inches in dimensions by balancing them one against the other, as nearly as might be, for the facility and dispatch of working by whole numbers. And that system was, of course, liable to doubt and question, because it was only an approximation towards accuracy; and this laborious and carefully prepared work was undertaken, it seems, in the just expectation that it would be appreciated and adopted by the mercantile world, and in all parts of the globe, as a ready-reckoner of exact dimensions for every description of package or production which modern trade is accustomed to class as light goods in the stowage of ships.

The method of the compiler, though at first it looks a little perplexing, becomes simple, intelligible, and easy of application as soon as his explanation is perused. Every bale or package is assumed to be evensided, and practically reducible to three principal measurements, like an ordinary piece of squared timber—length, breadth and thickness—and the contents are found to the hundredth part of an inch, by using in every case two places of decimals. The starting point is at 6 inches long, 6 inches wide and 6 inches deep, and advancing gradually by quarter inches to the largest-sized packages. Some idea may be formed of the immense number of separate sums which had to be performed and repeated before such a work could be presented to the public complete and accurate in all its parts, when we mention that about 450,000 such calculations are comprised in each volume, in verification of which certificates of accuracy from eminent and well-known authorities are quoted by the author in his preface.

Every quarter of an inch increase in the smallest of the three dimensions has sixteen pages of contents assigned to it at the various breadths of the other side, and the variations of length are also calculated to quarter inches, so that every case that can occur is provided for, and if a package or piece of merchandise-timber, for instance, exceed the length of the longest measurement set down, it is but necessary to take a section of it, say the half, quarter, or even one-eighth, and having found the contents of that, multiply it by the denominator of the fraction, and you have the true contents of the whole piece to the hundredth part of an inch, as if it had been so stated in the book. Such a work, of course, appeals strongly to the general body of the mercantile community in every nation and language, for scarcely more than three or four words of English, apart from the brief introductory explanation, require to be known to render it intelligible to all civilized peoples; *length*, *breadth*, and *depth* or *thickness* comprise its chief vocabulary, the rest consists of figures, which are universally understood. There is little to be read, but an immense deal to refer to, and the foreign trade of the world would be greatly facilitated by having such a standard of measurement to go by. That this work is not unworthy of such a high and authoritative position may be presumed from the circumstance that most of the eminent houses and great trading bodies of Bombay, Madras and Calcutta, as well as those of many other ports in the Indian seas and elsewhere, have given their names as subscribers to it and adherents to the author's system. This is of itself an immense testimony and recommendation, and there seems every probability that the time, money and intelligence which must have been so largely employed in getting up and producing to the world this really valuable work will, in the end, be amply rewarded. The two volumes are in large octovo, neatly bound in cloth, containing between seven and eight hundred pages each, and no shipper or shipowner's office should be without them.

We need only add that the way these volumes are turned out of hand is, we consider, highly creditable to the Caxton Press of Bombay.

Aid to Survey Practice. By Lowis D. A. Jackson, A.-M.I.C.E. London: Crosby Lockwood & Co. For sale by D. Van Nostrand. Price $5.00.

This book, which the author modestly calls a "small work on survey practice," will, we think, be found of considerable value to young surveyors and to articled pupils, for it had its origin in this way: Mr. Jackson, in his search for a work on Surveying, to put into the hands of his pupils, found many books excellent in their way, but none which would serve the purposes of the student and form a general book of reference for methods, formulæ, and forms of record. There was, in fact, no book that could be regarded as a general guide in survey practice, but the student anxious to acquire a tolerably wide knowledge of his profession would have needed a small library of books on different branches of the subject. Under these circumstances, Mr. Jackson was, perforce, compelled to give written instructions to his pupils, and these notes, condensed and revised, now appear in a moderate-sized volume for reference in surveying, leveling and setting out, and in route-surveys of travelers by land and sea. A considerable portion of the book is reprinted from the author's "Curve-book," and though some of the methods described are strictly original, in every case the systems are those which have been tested in practice. In many respects it will be useful to the trained surveyor, for it will enable him to refresh his memory and to shorten his labor by the use of tables and formulæ; while to those whose survey practice has been limited it will be a vade-mecum. The author says, however, that he did not write the book with the idea of making an utterly inexperienced person a surveyor, for that is a hopeless task, the art of surveying requiring a thoroughly practical, as well as theoretical knowledge of method. His purpose was to supply a guide, and he has certainly accomplished it. The work is divided into four parts, viz., general surveys, leveling, setting-out and route surveys, with a selection of field records to illustrate the text. There are also some page plates of different surveys to match the field records, and a number of diagrams to elucidate the text. The book is, in fact, almost indispensable to the student, while the traveler will find just the information he wants to enable him to take an ordinary route-survey, and to indicate with accuracy the general features of a district.—*English Mechanic.*

A Treatise on Statics.—By Geo. M. Minchin, M.A. Oxford and London: McMillan & Co. For sale by D. Van Nostrand. Price $4.00.

This is the second edition, corrected and enlarged, of a treatise on the fundamental principles of electrostatics and elasticity, which has found a place in the Clarendon Press series. The author, who is Professor of Applied Mathematics at Cooper's Hill, acknowledges the labors of correspondents who have supplied him with corrections of errors and lists of misprints, and in the present edition he believes that few can remain. The examples have been rearanged with reference to their relative difficulty, and some have been omitted, as being purely mathematical and fantastic. Some more important alterations or additions have been made, notably the introduction of a chapter on "Strains and Stresses," the author thinking that, in view of the enormous development of mathematical physics and the wonderful modern inventions depending on small strains and vibrations of natural solids, the study of the equilibrium and motion of bodies as they are, and not as they exist in abstraction, is a subject of which it is impossible to exaggerate the importance. He is clearly of opinion that too much valuable time is spent in the discussion of neat mathematical realities, though he is fully alive to the necessity for spending some time in such work. The chapter on strains and stresses refers mainly to the theories of light, magnetism and electricity, and are written for students who have attained proficiency in pure mathematics. For the view of the theory of friction presented in these pages the author is indebted almost entirely to Mr. Jellett, who has in his lectures and his treatise on the subject completely elaborated it. This volume will, we think, be the recognized text-book on statics in many of the higher schools and colleges, but it is rather too far advanced for those who are endeavoring by themselves to acquire the knowledge necessary to solve the problems which are daily cropping up in connection with mathematical physics. Those who are well grounded in the ordinary mathematics of the schools will be able to read it with advantage, and progress steadily to the higher branches; but the student who thoroughly comprehends all that is contained between the two covers of Prof. Minchin's "Statics" is very fairly equipped to battle with modern questions in electrostatics.—*Eng. Mechanic.*

MISCELLANEOUS.

A new Metallic Compound.—On Wednesday evening last Dr. Granville Cole read a paper before the Society of Arts on a new metallic compound discovered by Mr. J. Berger Spence, and its application to industrial and artistic purposes. The substance in question belongs to the class known as thiates or sulphur sulphides. Nearly a year ago Mr. J. Berger Spence discovered that the sulphides of metals, combined with molten sulphur, formed a liquid. This liquid, on cooling, became a solid, homogeneous mass, possessing great tenacity, and having a peculiar dark grey, almost black color. It has a comparatively low melting point, viz., 320° Fah., or rather more than 100° above the temperature of boiling water. There is thus in its favor the small amount of fuel needful to supply the necessary heat for reducing the metal to a condition for use. It expands on cooling, a property not shared by the majority of other metals or metallic compounds, and for an operation like the joining of gas and water pipes this expanding property is one of great importance. It claims to resist atmospheric or climatic influences, as compared with bronze and marble. As compared with other metals or metallic compounds, its resistance of acids, is certainly superior. A smooth surface of this metal or metallic compound, now known commercially as Spence's metal, takes a very high polish.

These qualities tend to render the new compound very useful in many ways. The advantages which Spence's metal possesses over other materials used for artistic productions, may be summarized under three heads, viz., cheapness, facility of working, and resistance to climatic influences. As compared with lead, which is one of the cheapest of metals, it is one-third the weight; and whereas the average cost of lead for the last ten yeas has been nearly £ 18 a ton, Spence's metal only costs £ 15. A ton of Spence's metal being three times the amount in bulk of that of a ton of lead, it is available for three times the amount of work. It may, therefore, be considered to be nearly a quarter of the price of lead, and, consequently, very considerably less than that of bronze. Its melting point being very low, allows it to be very easily prepared for pouring into a mould, and its property of expansion, when cooling, causes it to take such a perfect impression, that the cast requires very little chasing after. In respect of a gelatine mould, which can cover a considerable surface of work without joints such as one has to make in plaster piece moulding, the metal cast obtained from such a mould would require no chasing. With regard to its resistance to climatic influences, experiments have been conducted in this direction with complete success. A polished surface of the metal has been exposed for six months in all weathers, without showing the least change.

Experiments have been made which show its great suitability for joining gas and water pipes, and from a sanitary point of view, as water has no action upon it, it would be extremely valuable for cisterns, and being almost a non-conductor of cold, pipes might be lined with it to prevent the water from freezing. To chemical manufacturers, the metal being less acted upon by acids than other metals, it may also be of service, especially as regards sulphuric acid, which is the most extensively used of all acids in commerce. The new metal has been tested with sulphuric acid, and its action is almost imperceptible. The one objection to the use of this metal in this case is its low fusing point, but when acids have only to be used up to a certain temperature, say 200° Fah., a large field may be predicted for its use. Besides the uses thus enumerated, Dr. Cole indicated many others to which the metal may be applied; for instance, joining iron to stone or wood, the tensile strain of the metal being from 650 lbs. to the square inch five minutes after setting. For joining railings to stone it would, he said, answer equally as well as lead, and be very much less in cost; also for coating the holds of ships. It might also be used for hermetically sealing bottles; for covering cloth; for covering parcels that are being sent out to hot climates, thus obviating the use of the lined boxes; for preserving fruit, or other articles of consumption.

Ancient Petroleum.—Professor Skeat has printed in the *Athenæum* a passage from North's translation of "Plutarch's Lives" (1631, p. 702), from which it appears that Petroleum was known in the time of Alexander the Great. The passage runs as follows:—"For a Macedonian called Proxenus, that had charge of the kings carriage [baggage], as he digged in a certaine place by the riuer of Oxus, to set vp the kings tent and his lodging, he found a certaine fat and oily veine, which after they had drawn out the first, there came out also another clearer, which differed nothing, neither in smell, taste, or savour from natural oile, having the glosse and fatness so like, as there could be discerned no difference between them: the which was so much the more to be wondered at, because in all that country there were no oliues.

The rival merits of the Mont Blanc and Simplon routes for the new railway tunnel through the Alps have recently been attracting a good deal of attention in Switzerland and Savoy. The Swiss at first considered the proposal to drive a tunnel through Mont Blanc instead of the Simplon hardly worth notice; but since it has been taken up with such spirit by M. Chardon, a member of the French Senate, the project has assumed practical importance, and has received serious attention. In Switzerland, the Mont Blanc route is not, says the *Times*, regarded with favor, partly because it would not touch Swiss territory. The supporters of the Simplon route, moreover, urge that the line from Calais to Plaisance through the Simplon is 136 kilometers shorter than that through Mont Blanc, and that the Simplon tunnel would be at a level 500 meters lower than that through Mont Blanc. Further, it is pointed out that the lines of approach to the Simplon have already been constructed, while Mont Blanc is far less favorably situate in this respect. In Savoy, on the other hand, the general feeling is strongly in favor of the Mont Blanc route—first, because it would be on French territory; and, secondly, because it would greatly benefit the Savoyards.

The Suez Canal.—The total receipts of the Suez Canal for the year 1879, were £ 1,185,200. This showed a decrease of £58,700 on 1878, which year itself was £ 67,100 worse than its predecessors. As might be expected, however, the later months of 1879 were much more satisfactory than the previous period of the same year. The receipts for December were £ 107,600, an increase of £ 9,200 on the same month of 1878. The return for the first half of January shows an increase on that of the same period last year of £ 20,800. Should the favorable tendency here indicated continue, they will be another proof of the reality of the improvement that has taken place in the trade of the world at large.

VAN NOSTRAND'S

ENGINEERING MAGAZINE.

NO. CXXXVIII.—JUNE, 1880.—VOL. XXII.

THE THEORY AND CONSTRUCTION OF THE LEADING FORMS OF ELECTRO-MOTORS, AND THEIR EMPLOYMENT IN THE PRODUCTION OF THE ELECTRIC LIGHT.

By Prof. HENRY MORTON, Member of the Light-House Board.

II.

THE LONTIN MACHINES.

Among the machines for generating electricity that have commanded more or less of general attention may be included the magneto and dynamo-electric machines devised by Lontin. In their mode of construction and arrangement these machines possess features which recall the Alliance and Holmes magneto-machines on the one hand, and the Siemens and Gramme dynamo-machines on the other.

There are two styles of Lontin dynamo machines, the one yielding continuous currents of one direction, and the other producing alternating currents.

In the machine of the first form, a number of bar electro magnets are disposed radially about a central shaft of soft iron, and the star-shaped wheel thus formed is made to revolve between the poles of an ordinary powerful U-shaped electro magnet. The wire of the electro-magnet wheel forms one complete circuit, and is connected at the several points of juncture of each two successive magnet coils, with the appropriate section of a commutator, placed upon the axis of the machine. On revolving the wheel between the poles of the stationary upright field magnet it will readily be seen that, considering any individual radial electro magnet, there will be induced in the coil of the latter, during its motion away from one pole and its consequent approach to the opposite pole, a current which, though varying (first diminishing and then increasing) in intensity, will still maintain a constant direction until the coil has arrived at the opposite pole, where a reversal of the current will take place. The current will continue flowing in this new direction until the revolution of the wheel brings the coil back to the pole from which we have considered it to start, when and where the current will be restored to its former direction. At any moment, therefore, during the revolution of the wheel, all the electro-magnet coils in the upper half of the wheel will be traversed by a current flowing in one direction, and all those in the lower half by one in the opposite direction. Elastic strips, one on each side, bear against the commutator in the line where the reversal takes place, and lead away the currents to the proper binding-posts. The mode of generation and direction of the currents in this form of the Lontin machine is thus seen to be exactly similar to that obtaining in the Gramme machine.

The stationary electro magnets are

included in the main circuit, in accordance with the dynamo-electric principle. By mounting several of these wheels of electro magnet, with separate comutators and field magnets, on the same central shaft, an equal number of independent currents may be obtained, which by appropriate means may of course be combined in any desired manner.

By winding the alternate electro magnets on each wheel in opposite directions, the machine may be made to produce currents constantly varying in direction. The Lontin machine proper, for alternating currents, has, however, a more elaborate form, bearing a rather close resemblance to the machine devised by Holmes.

This Lontin machine consists essentially of an electro-magnet wheel, like that in the first described form of the machine, only that the magnets are much more numerous, amounting in number to twenty-four and over, and are wound in the manner just referred to—that is, the alternate magnets are wound in opposite directions; and of a large stationary soft iron ring surrounding this wheel concentrically, to which ring there are secured, at equal distances apart, a number of short electro magnets, equal in point of number to the electro magnets on the inner wheel. The electro-magnet coils of the revolving wheel are connected together, so as to form one circuit. The current necessary for the saturation of these magnets is obtained from an auxiliary machine (a Lontin machine of the first form, for instance), mounted upon the same axis, connections being so made, by means of brushes and collars, that the rotation of the large wheel does not interfere with the circulation of this current. The ends of the electro magnets, during the rotation, pass very closely by the cores of the outer stationary magnets, and as the successive magnets on the wheel present opposite poles to the cores, constantly alternating currents are induced in the outer magnets. One series of terminals of the coils of these magnets is led to one binding post, while the other passes to a set of circuit-closing devices, by means of which all of the currents, separately or together, or any individual one or ones, may be conducted away from the machine.

The great merit of this second form of the Lontin machine lies in the facility with which currents varying in number and intensity may be derived from it, so that quite a number of electric lights may be produced at the same time, and also in the fact that in the conducting away of these currents contact brushes are entirely dispensed with; so that the great loss in electricity attendant upon this mode of collection, besides the frequent attention required by its use, is entirely avoided.

With a velocity of rotation of 320 turns per minute, the machine being arranged so as to yield 12 separate currents, the outer magnets being connected together two and two for this purpose, 12 lights were obtained, each equivalent to 740 candles. Three series of 8 magnets each gave 3 lights, each having an intensity of 1,480 standard candles.

It is said that to prevent any detriment to the machine arising from the conversion into heat of any currents that may not be required, while the remaining ones are being applied to some special purpose, these superfluous currents are made to pass through appropriate resistance coils, and thus become in a manner absorbed.

This may of course prevent such mischievous or destructive effects, but in no wise diminishes the loss of efficiency involved in the production of this amount of electric energy, from which no useful effect is obtained.

A large Lontin machine of the kind last described was used at one time for lighting the railway depot at Lyons, where it fed 31 separate lamps, each giving out a light of about 340 candles. The power needed to run this machine is not stated. Another machine of this form, giving 24 lights of 1,480 candles, required from 20 to 22 horse-power to drive it. Smaller machines, of from 2,000 to 3,000 candles, demand somewhat more than 5 horse-power.

SIEMENS NEW MACHINE.

Siemens and Halske have lately devised a new dynamo-electric machine, for the production of one or several independent currents, which may be made, at pleasure, either intermittently unidirectional or rapidly alternating in character.

In one form of this machine the two sides of an upright iron frame carry each a series of 8 circularly disposed electro magnets, the cores of which stand out at right angles to the sides, and carry at their ends, where they face the corresponding cores of the opposite series, large, flat plates of soft iron. The plates of each set are alternately of opposite polarity, while those facing each other exhibit the same polarity; and as the space between them is made as small as the mode of construction will permit, magnetic fields of high intensity and of alternately opposite polarity will come to be formed.

Upon a shaft running through the center of the frame there is secured a disk, carrying on its circumference an upright iron ring, oblong in section, made either of wire or plates, sometimes also of massive iron. This ring is surrounded at eight (or more, in some forms of the machine) equi-distant places by flat coils of insulated copper wire, which, with the ring, are carried by the

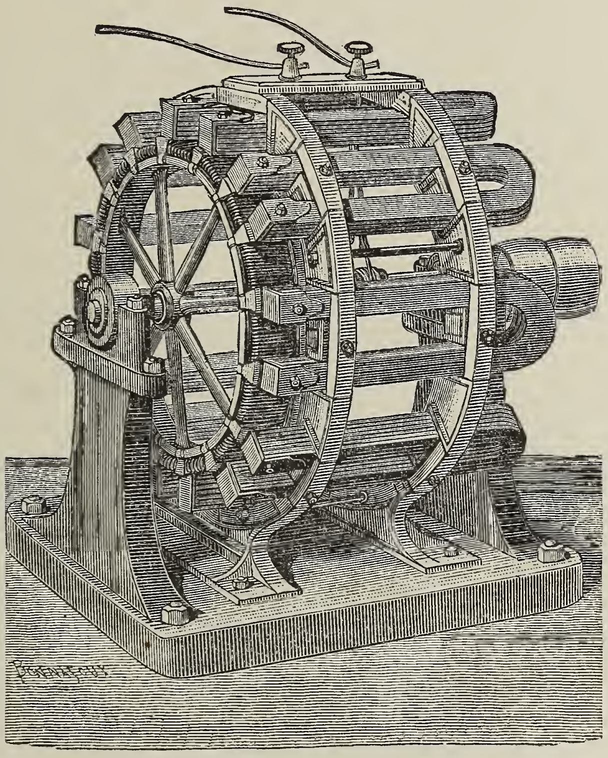

Fig. 37.

rotation of the shaft through the magnetic fields formed by the electro magnets. Two of the coils on the rotating ring are devoted exclusively to the purpose of keeping the field magnets saturated, in accordance with the well-known dynamo-electric principle; and since the current in this case must be constant in direction, a special commutator is provided to secure this result. The alternating currents obtained from the remaining coils are conducted away from the machine by means of collars and brushes in the ordinary manner.

The great resemblance of this machine to a machine of the Brush form, in which eight sets of electro magnets are employed, instead of the usual two, need scarcely to be pointed out.

Several forms of the machine above described are manufactured by Siemens and Halske, the details varying with the purposes to which it is intended to apply any particular machine. The larger machines possess one important distinctive feature, in that no iron is made use of in the construction of the revolving disk, the cores of the coils being formed of wood or some other non-magnetic material. By this mode of arrangement the hurtful inductive effects, the production of Foucault currents, the loss of power by conversion into heat, and the like, attendant upon the use of iron in this connection come to be entirely avoided.

THE DE MERITENS MAGNETO-ELECTRIC MACHINE.

While most of the recent inventors and improvers of magnetic machines have abandoned the use of permanent magnets, one, M. De Meritens, has thought best to return to this feature of the earlier forms. There is certainly this to be said in its favor, that if equal power in permanent magnets could be obtained without too great cost of material and inconvenience, a machine so constructed would be theoretically more economical than one on the dynamo-magnetic principle, since the energy expended in producing and maintaining the magnetic force of the field magnets in such a machine is a total loss as regards the ultimate available current from the machine.

The difference between a magneto- and a dynamo-electric machine in this view would be essentially like the difference between a watch whose spring, being wound up in the usual way, was prevented from running down or unwinding at the inner end by a ratchet, as is usual, and one in which this unwinding was prevented by the constant motion of a friction coupling of some sort. In other words, in the dynamo machine, we substitute energy as a retaining power for the mere statical force supplied by the permanent magnet. The energy costs something all the time, the statical force nothing but what is involved in the first cost of material.

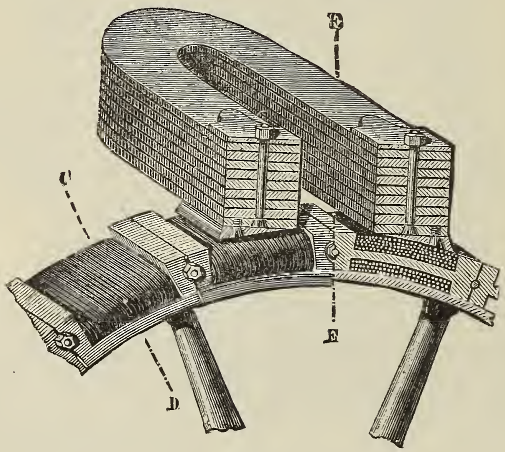

Fig. 38.

It might therefore be asked, why dynamo machines, as a rule, were, in fact, more economical in working than the early magneto machines, such as the Holmes and Alliance machines.

The obvious reply is that the enormously greater power which could be concentrated in the electro magnets of the dynamo machines diminished their weight, size and number of parts in a like degree, and so reduced the losses from friction, resistance of conductors, and the like, which exist in the large, heavy, and multisectional magneto machines.

If, however, it should become possible to make permanent magnets equal in power to the field magnets of the dynamo machines, then, undoubtedly, a machine constructed with such magnets would possess decided advantages as regards "duty," or economy of driving force.

The De Meritens machine seems to be an effort in this direction. It consists of a series of powerful steel magnets, built up of thin plates, as shown in Fig. 38, supported in a circular frame, within which revolve a series of coils mounted on the periphery of an interior wheel, as shown in Fig. 37.

Though great claims have been made for this machine, it does not seem to differ sufficiently from the earlier magneto-electric machines to account for any such great superiority in results.

In addition to the other machines which I have already mentioned are several which should by no means be passed over without notice.

Thus, in the first place, Mr. Edward Weston, of Newark, N. J., is manufacturing a machine which in general appearance so closely resembles that of Siemens, shown in Fig. 24, that this wood-cut would answer very well as a representation. There are, however, several important differences of construction and interior arrangement, and a careful series of experiments, as will appear further on, has shown that its performance is very remarkable as compared with the Siemens and other forms which have been here tested.

Another machine which has met with some success in practical application is that manufactured by Messrs. Arnoux & Hochhausen. In general structure it much resembles the second form of the Wilde or the Farmer-Wallace machine.

In describing the various forms and modifications of these machines I have not attempted in all cases to follow the chronological order of each step, as this would sometimes have involved the skipping about from one type of machine to another. I will now, therefore, give an abstract of the chronology of the subject, following Dr. Schellen's book already quoted, and to which I am indebted for many of the engravings of machines, &c., with which this report is illustrated for a part of the list:

1831. Faraday discovered magneto-electric induction.
1832. Pixii made first magneto-electric machine.
1833. Saxton made magneto-electric machine.
1833. Clarke made magneto-electric machine.
1849. Nollet-Van Malderen, Alliance machine.
1852. Holmes improved form of above.
1857. Siemens introduced peculiar armature.
1864. Pacinotti, the first continuous-current machine.
1866. Wilde made his first form of machine.
1866. Siemens & Halske, same principle as Ladd.
1867. Ladd, self-exciting principle.
1867. Wheatstone developed same principle.
1871. Gramme first described his continuous-current machine.
1873. Wilde describes his second form.
1875. Siemens describes his machine.
1873. Farmer patented machine like Wilde's second.
1874. Lontin machine, for many circuits.
1878. Gramme's alternating machine.

In considering the application of the electric arc as a source of light, it becomes very important to notice with accuracy just what is the chief location of light in the ignited poles, and how this may be affected by various conditions.

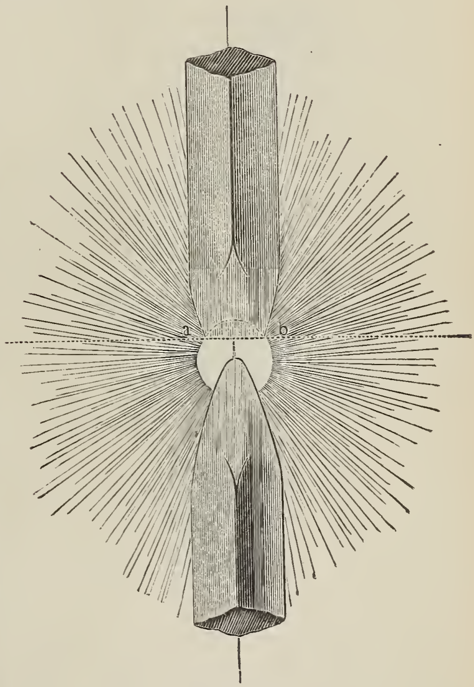

Fig. 39.

Thus, in the first place, if we are using a machine with a current of uniform direction, we will find that the upper or positive pole, as they are generally arranged, soon acquires a cup-shaped form, as shown in Fig. 39, and that the most intensely luminous portion of the carbon is the interior of this positive cup. The edges of this cup will evidently cut off this light from spreading upward for a very considerable angle, while on the other hand all the light from this interior luminous area will pass freely downward. From this it will of course follow that very different results would be obtained if, with such machine and arrangement of the carbons, the lights were measured from below, or on a level, or from above.

If the two carbon points are not placed truly in line with each other then we have such a state of affairs as is shown in Fig. 40.

Here, evidently, while the light from the hollow positive pole would radiate freely in front, it would be largely cut off behind, and escape only with a medi-

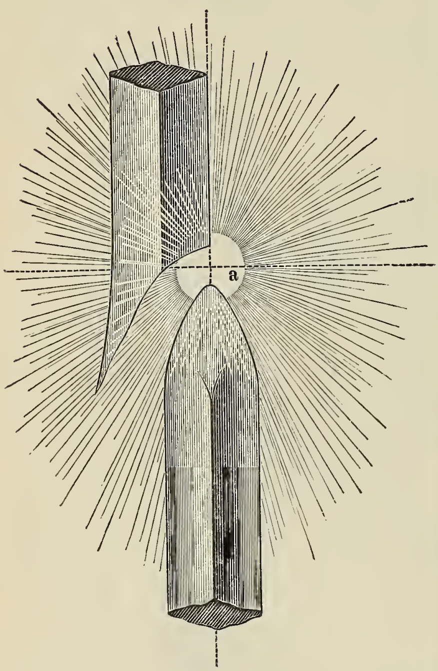

Fig. 40.

um degree of facility at either side; in fact, measurements made with such arrangement show the following figures:

Representing by 100 the light emitted, in a horizontal position, when the points are in line, we have for the various directions, when they are displaced as shown in Fig. 40: In front, 287; laterally, 116; backward, 38.

In the report of experiments made by a committee of the Franklin Institute (see Journal of that Society, vol. 75, p. 301) I find the record of a similar set of measurements as follows:

Front	2,218	candles
Side	578	"
Side	578	"
Back	111	"
	3,485÷4=871	

"The light produced by the machine, under the same conditions, except the carbons being adjusted in one vertical line, was 525 candles. This would seem to indicate that nearly 66 per cent. more light was produced by this adjustment of the carbons; but a close study of the conditions satisfied us that such is not the case, and that there is no advantage to be derived from such adjustment, except when the light is intended to be used in one direction only."

This shows us, among other things, how very great a difference of result in candle-power may be obtained with the same apparatus, if a difference occurs in the arrangement of the points; and it also explains why an arc which gives a very high candle-power when measured, may quite fail to exhibit anything like an equal degree of actual illuminating power when put to some practical use.

Thus, in the case just cited, while the candle-power, measured from the front, would be 287, the average for all directions would be only 139, or about one-half as great.

In this connection a certain advantage is found in the use of machines with alternating currents. Here the carbons both burn away alike to pointed ends, and the light is thus much more equally distributed on all sides. (See Fig. 41.)

In most of the machines now in use the current which produces the light is the same which passes around the coils of the stationary magnets, by which the field of force is developed; hence there is the most intimate relation between the machine and the lamp, and any fluctuation in the resistance offered at the latter is at once felt at the machine. To eliminate this source of uncertainty and irregularity, in some experiments which I have lately conducted with various machines, I have employed a simple, substantial holder for the carbons, with means of adjustment from time to time by hand. This requires, of course, the frequent attention of an assistant during the experiments, but it has in many instances enabled me to eliminate all question of the influence of the lamp on the running of the machine.

In this connection it would be very appropriate to discuss the construction and merits of the various forms of electric lamps, but this subject I must defer for the present on account of lack of time to arrange the great mass of material here presenting itself, and leave this to be taken up in a subsequent report.

Among the various machines which have been above described, those which have been submitted to trial by your committee during the last year are the following:

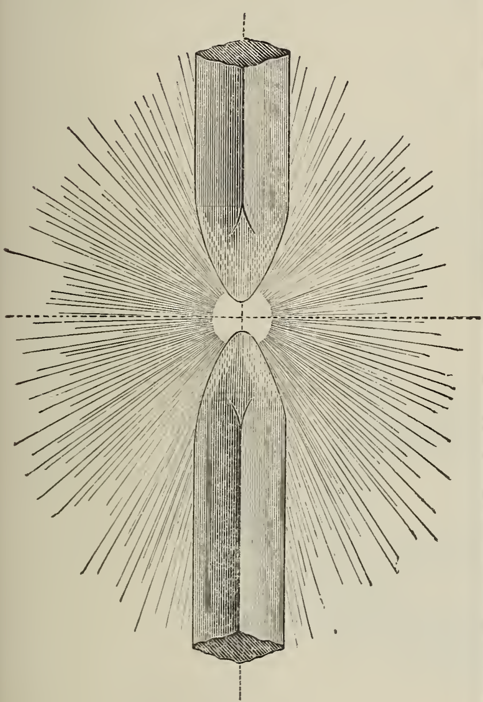

Fig. 41.

The Siemens machine, of the form shown in Fig. 24.

The Wallace-Farmer machine.

The Brush machine.

The Arnoux and Hochhausen machine.

The Weston machine.

The Maxim machine.

Preliminary trials having indicated that the Wallace-Farmer and the Arnoux and Hochhausen machines did not promise to afford results suitable for the purposes contemplated in this examination, they were withdrawn from further test and the work was continued on the other machines alone.

Of these, two machines, each of the Brush, Weston, and Maxim types, were thoroughly tested, so that, in all, seven machines have been tested by your committee in a very thorough manner, involving a very considerable expenditure of time. As this has been taken from days already overcrowded with other duties, but little opportunity has been left for such a thorough scientific discussion of the whole subject involved as I should have wished to give, and I have been obliged to avail myself of such material as I could utilize in the illustration of the subject. The first and all-important object was to find which, among the various machines readily attainable, was best fitted for use in the Light House Department, and all other considerations were of necessity postponed to this.

Having this in view, I confined my tests essentially to the measurement of the light actually obtained from the electric lamp, and to the power actually expended in running the machine.

For determining the former, I employed a Sugg photometer of the usual form employed in measuring the candle-power of ordinary illuminating gas.

This apparatus was inclosed in a temporary dark-room, built of wooden frames, covered with black oil-cloth, which was placed at one end of the physical laboratory of the Stevens Institute of Technology. In this dark room the photometer was so set as to have its candle end towards the distant side of the room, where the electric lamp was arranged opposite a door opening into a dark passage-way of considerable width beyond, thus securing a non-reflecting background to the electric light when desired.

In testing a light, at first the apparatus was employed in the usual way with a pair of standard candles as the standard light; afterwards a Sugg standard burner of 15 holes at the further end of the photometer was standardized with a pair of weighed candles, and this burner was then used as the standard for comparison with the electric light. At the same time the power employed in driving the machine was taken by the use of a transmitting dynamometer, designed by Mr. William Kent, a graduate of the Institute, and built in the workshops of the Institute by the graduating class of 1879. This is, in fact, a modification of the dynamometer invented by Mr. Samuel Batchelder, of Boston, nearly forty years ago, a description of which may be found in the Journal of the Franklin Institute, 1843, vol. xxxii, p. 277, and in the Scientific American of August 31, 1878. The modification consists in providing a method of making an automatic record, and of indicating more minute variations of the power transmitted. The accompanying cut, Fig. 42, represents the dynamometer without the recording attachment and as it was used in the experiments. The construction of this apparatus and its mode of operation are as follows:

It consists, as shown, of two stout cast-iron frames, held together by bolts in bearings, in the top of which frames run two shafts, each carrying a pulley at its outer end and a bevel-gear wheel of 45° at its inner end. One of these shafts is the driving-shaft, connected by

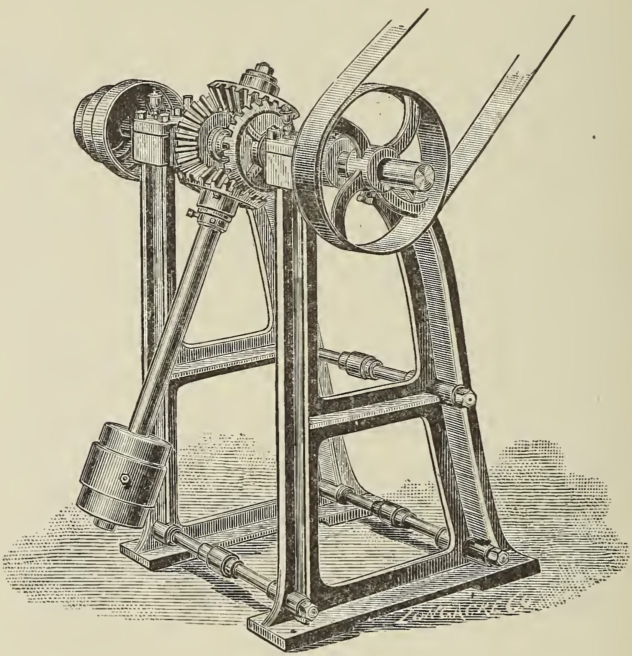

Fig. 42.

belt to the engine or other prime mover; the other is the driven shaft, connected by belt to the machine driven. The power is transmitted from one shaft to the other through two other bevel-wheels of 45° gearing with the first, the shaft common to them and on which they run freely being at right angles to the axis of the two shafts first mentioned, and carrying at one extremity a heavy pendulum.

The bevel-wheels being connected, as shown, and the power being applied to the driving-wheel, the two intermediate wheels with their common shaft have a tendency to revolve around the driving-axis, which tendency is a measure of the force transmitted, and is resisted by the moment of the weight of the pendulum. In the Batchelder dynamometer the four bevel-wheels and their shafts are used, but the shaft connecting the intermediate wheels is always held in a horizontal position, and its tendency to revolve is resisted by weights and a sliding poise applied to an extension of one end of it, which is graduated like a scale-beam. In using the Batchelder dynamometer the operator requires to keep the beam constantly balanced, by shifting the poise on the scale-beam or the weights in the scale-pan hung at its outer end, to correspond with the variations of the power transmitted, and a record of the power is obtained by noting the weight on the scale-beam at each instant, and the corresponding number of revolutions of the driving-shaft. The horse-power is obtained by multiplying weight in pounds of weighting poise on the scale-beam by the distance in feet of its point of suspension from the driving axis, by the number of revolutions per minute, by 3.1416, and dividing by 33,000.

In the improved dynamometer the horizontal scale-beam with its weights and sliding poise has been dispensed with, and the swinging pendulum substituted. The tendency of the shaft carrying the two intermediate bevel-wheels, the prolongation of which shaft is the pendulum arm, to revolve around the driving-axis, is measured by the weight of the pendulum and its arm multiplied by the distance of their center of gravity from the driving-axis and by the sine of the angle which the pendulum arm makes with the vertical. When the pendulum hangs in a vertical position the force transmitted is zero, errors due to friction excepted, and when it is horizontal, the sine of the angle being equal to unity, the force is the maximum the apparatus is capable of recording. The weight of pendulum and its position on the arm being constant, the only variables to be considered in measuring the horse-power transmitted are the number of revolutions per minute and the sine of the angle of the inclination of the arm. These variables may be caused to automatically record themselves on a sheet of cross-section paper by any one of a number of devices.

The dynamometer used in these experiments has a capacity for measuring 20 horse-power; a method is provided of measuring very small powers, which consists in lessening the moment of the pendulum and arm, first by shifting the sliding weight nearer the driving-axis; second, if still lighter moment is desired, by removing the weight from the arm entirely; or, third, if even still greater delicacy is desired, by counterbalancing the weight of the arm by adding weight to its upper end, above the upper intermediate bevel-wheel.

During the experiments one person attended to the running of the engine, dynamometer, and machine, while another recorded the number of revolutions of the dynamometer and the inclination of the weighted pendulum; the latter was read from a graduated arc fastened to the pendulum in such a manner as to be in the same plane with its axis; this arc, by the deflection of the pendulum, swung by a pointer attached to a cross-bolt at back of machine, and thus indicated the degrees of inclination of the pendulum. The friction of the dynamometer was obtained by loading its delivery shaft with a weight which produced the same pressure on the bearings as was brought on them when it was transmitting power to the light machines, and then noting the deflection of the pendulum to overcome the friction produced.

In the earlier experiments the readings of the dynamometer were recorded every fifteen minutes and in the later ones every five minutes.

Photometric measurements were also made simultaneously with the reading of the dynamometer, and occasionally one or two between successive readings of the dynamometer.

The tests of machines and lamps for producing the electric light herewith reported, may be divided into two principal groups.* The first group consists of those in a certain sense preliminary, which were made at first to test various general questions, such as the effect of a displacement of the carbons out of a vertical line, the different amount of light given out in different directions under this condition, and the like. In these tests the standard of light employed was a pair of standard candles. In these experiments less frequent readings of the dynamometer were taken, and the results are not regarded as so closely accurate as those obtained in the second series, where a standard 15-hole Sugg burner was used as the light-unit of comparison, and where the dynamometer and photometer readings were taken simultaneously.

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* The tables here referred to, twenty-six in number, giving the details of the experiments with different machines, are omitted.

It was deemed sufficient for the purposes of this article to exhibit Table No. 27 of the Report, and to state that the results given represent the averages of several trials of each of the machines—eleven of the Brush Machines, eleven of the Weston, three of the Maxim, and two of the Siemens; the experiments, in many cases, having been continued for a number of hours consecutively.—[Ed.]

Table of Averages.

Machine.	Lamp.	Average candle-power.	Average horse-power.	Average candle-power per horse-power.
Maxim (ordinary type)	Maxim	3,297	5.483	729
Maxim	Hand-lamp	3,930	5.585	704
Siemens	Siemens	4,651	4.863	956
Siemens	Maxim	4,548	4.742	959
Weston	Hand-lamp	8,585	4.769	1,800
Weston	Maxim	7,787	4.683	1,663
Weston	Siemens	7,262	5.056	1,436
Weston	Weston	6,063	4.552	1,332
Maxim (with magnets of low resistance)	Maxim	7,524	7.400	1,017
Brush	Brush	4,365	2.8467	1,533
Brush	Siemens	3,532	2.9573	1,194

HOW SHALL AN AMERICAN MAN-OF-WAR BE BUILT?

Written for Van Nostrand's Magazine.

By C. A. E.

This question will soon present itself to us for solution. We cannot go on much longer with the few old ships to which we are now reduced. We have waited long enough besides for European experience. A score or so of staunch, serviceable, sea-going boats we must possess. We have to maintain squadrons of a few ships each in the different seas to protect our private and national interests, especially in the neighborhood of those countries loosely governed and in a chronic state of revolution, which at frequent intervals are found violating not only principles of international law but the very dictates of humanity. As a school, too, where to train a reliable and sufficient number of officers and seamen for cases of need, a moderate navy is indispensable. It is a well-known fact that in our naval wars we have been sadly in lack of good American seamen; and had we not been more fortunate with regard to officers, we should have fared badly indeed. Although by tradition and sentiment a pacific people, eager to uphold, through moral influence, international law, and to enlarge the sphere of its operations, yet we should always have back of us *some* physical force, if we would command proper respect among nations armed to the teeth, and valuing highly the possession of ready power. We are certainly not going to fight when we can arrange amicably the matter in dispute; but experience warrants the assumption that our honor, like that of any other nation, is liable at times to be so grossly outraged as to make the people demand with one voice war—and nothing but war. In this event we must have some navy to begin with, for in all probability the fight will be on the sea.

Descending to technical points we may remark that modern ships of war are, and will be, distinguished for some time to come by having as offensive weapons rams and heavy guns, and as a defence armor-plating of a variety of thicknesses and variously arranged. Rams and plating followed, as a natural consequence, the introduction of iron ships and heavy ordnance, and with these only will they disappear. The methods of making rams most effective, their shapes, their sizes, the thicknesses of plating, its quality and arrangement, are the questions to be studied to-day, and not their abolition. Some prophesy that torpedo warfare will become so perfected that ships will fight with them instead of with guns; but at an equal pace will protection against them have advanced, and rams and guns will continue as before to settle the battle. The world possesses to-day experience sufficient to prove the great efficacy of ramming. Numerous compartments across a vessel may possibly prevent her from sinking when rammed into once, but the second or third time she will, in all probability, go to the bottom. She will be more or less disabled at the first blow, and completely so if she receives it where her engines are, or where some other important part of her mechanism is, located. A ship which is designed essentially as a ram may have every one of her guns knocked to pieces, her crew two-thirds killed and wounded, her deck swept by a terrible fire, her hull above and even at the water-line pierced in many places, but, provided her engines are well protected and remain uninjured, she may be yet made to sink her adversary if she is well handled, and is superior to the latter in speed and evolution. Until her engines are destroyed, she has lost the smaller part of her aggressive character.

Without sacrificing advantages, armor cannot be placed sufficiently thick on a war vessel to prevent an ordinary heavy shot either from going completely through it, if fairly struck at close range, or at least from being shaken out of place. Armor should be thick enough only and so disposed as *to deflect* as often as possible a shot; it should be arranged, in other words, so that it may be very often hit at a pretty acute angle. Where it is really most needed, and should be thickest, is by the engines, especially if they project above or reach near the water line, and for short spaces in front of the guns; all other parts of the ship may have it considerably thinner. The idea which seems so prevalent in Europe of making a war vessel invulnerable nearly everywhere is undoubtedly a wrong one. She is but little less effective in a fight for being riddled at all points except at her engines and guns; the more so if she be arranged inside as to make easy repairs to leaks, and prevent the water from passing from one deck to the other. All, probably, of her mechanism may be kept below the water-line and remain safe. Although over those parts of her hull which must be well protected, comparatively thick armor-plating would appear indispensable, yet at all other points it loads the vessel, and takes away from her efficiency in several very important respects that cannot be sacrificed to invulnerability.

Turrets are objectionable on account of their weight, the limited view from their ports, the really small protection which they afford to the guns, their liability to become jammed when struck very low, the injurious concussions which are experienced inside, the demoralization produced by a shell penetrating and bursting among the gunners. When a ship can well bear the load of a couple of turrets, she would be more formidable if this weight were thrown into several additional guns, and would possess besides better sea-going qualities. So far as the men are concerned, a turret may protect them; but their safety is the least important matter in a fight; those who have fought on vessels prefer to do so in the open, where they are not cramped for room, where they can see more and to greater advantage what is going on. They care nothing for the protection of the turret; on the contrary, they sometimes fear in a turret when they would not outside of it. In the old style of vessel nothing was thought of fighting on an open deck; why should it be different now? Was a four or five inch shot safer to stop then than a nine or eleven inch one is now? As regards the guns, on the other hand, they are almost as liable to be hit projecting out of black port-holes as over a bulwark. A gun itself does not require much, if any, protection; a shot which strikes it is very apt to glance off, especially if it is a large, heavy piece; its carriage, however, demands some protection, although a turret is not necessary for the purpose. Since a monitor carries only one or two very heavy guns, toward which all the fire from a battery may be directed, they need every possible chance of protection. Hence the advisability of turrets for this class of ship. The guns of a sand fort project slightly only above earth-work, and are worked to great advantage against vessels; those of ships, if mounted in the same way over the bulwarks, would be equally efficient against either floating or stationary batteries. We may conclude, therefore, that apparently a sea-going man-of-war, of a number of guns, needs no turrets or other covered protection; the omission of which does not increase in an important degree the chances of having her armament disabled.

Let us pass next to the third peculiarity of modern warfare; heavy guns. The delicate monsters which are at present the rage in Europe, are pure extravagances. A war vessel should undoubtedly carry a few heavy guns of as high penetrating power as is consistent with the size of ship, the durability of the guns, their reliability, fast firing and easy handling; and those which throw projectiles weighing two hundred or three hundred pounds fulfill well the foregoing conditions. They certainly are amply heavy for the style of vessel we have in view. In fighting another, a ship should use as often as she can her heavy guns; in order to produce as much effect as possible on her opponent's armor; when she is obliged to attack a fortification, she should bring to bear on it as many guns as she can, because the number of shots she can throw into it more than their size, renders her formidable under these circumstances. Consequently she ought to carry, besides her heavy guns, a pretty good battery of others about one-half as powerful. Even when attacking a floating adversary such a battery may produce important effects. As an open deck vessel, which is the kind we are considering, in approaching close to an antagonist may have her deck swept by the latter's Gatling guns, she must carry herself, in the third place, a good number of the same guns favorably located, to reply to this kind of fire.

It is very improbable that an American man-of-war will ever be built in imitation of the monstrosities of Europe. They are too costly to construct and maintain, and besides are too large and of too deep draught to suit our needs and purposes. They are not good sea boats; for which reason they are disliked by naval men all over the world. So enormous is their weight that they do not ride well in the water, in spite of their great beam, and do not sometimes obey satisfactorily the helm. They consume an enormous amount of coal. They are too slow. Speeds of thirteen and fourteen knots per hour, in quiet water, have been assigned to them; but it is doubtful whether the fastest heavy iron-clad afloat steams at sea, under impartial circumstances, ten knots regularly per hour. Some five or six hundred men at least are *inclosed* in them, and should one of them happen to be blown up with a torpedo, or rammed down by another vessel, the sudden loss of life is terrible to contemplate; and must produce a great demoralizing effect in a fleet. Everything connected with them is on such a large scale that, considerable steam or hydraulic power has to be invoked for almost every operation. They are consequently filled with machinery, which very like may be injured or get out of order somewhere in a critical moment, and disable the ship in an important particular. The repairs to this machinery are expensive and of constant recurrence. A fighting vessel, on the contrary, should have as little machinery in her as possible, and that in great part, if not in whole, below the water line, grouped closely together, very accessible, and well protected at exposed points. Every operation that may be effected with manual labor and skill, should be so effected; for on a man-of-war these agents are not wanting.

Keeping in mind the fact that, our navy will be always small, the vessels composing it should be distinguished for speed; in order to derive the utmost service from them in cases of need. On the declaration of a war they may be scattered all over the world, and until we are properly equipped, may be required close at home; therefore they should be able to reach our shores in the shortest time. Once here they have to guard an extensive line of sea coast, and should be able to fly to any point suddenly threatened. On the sea they may have to chase fast merchantmen and faster privateers of the enemy. Performing blockade duty, again, their speed is of greater consequence than any other quality. If one of them should happen to be pursued by one or several men-of-war of the enemy, she ought to be able to save herself from fighting against disadvantageous odds. If, in her turn, she is chasing another vessel, she ought to come up to her as soon as possible, and with her ram principally decide the contest. To render herself formidable as a ram, however, she must be swift; her blow will then be given with more than ordinary effect, and should she miss her opponent the first time, she will sweep past her quickly and return as quickly to the charge, exposing herself a short time only to fire. Her good speed will favor her also in not permitting her opponent to get out of her way.

She will require to be driven with twin screws, moved by two powerful engines. All the room necessary for the proper arrangement of her engines, the number of her boilers, and the size of her coal bunkers, should be taken, even if she remain cramped for space in other particulars. As her crew all told will reach somewhere between 250 and 300 men, and her guns large and small will number from 12 to 14, her length, to enable her to sustain regularly a good speed with moderate consumption of coal, must be about 270 or 280 feet. Her speed should be 13 knots per hour, when the ship is uninfluenced by wind or current; and by forcing her engines and boilers, and consuming about 30 per cent. more coal, between one and two more knots per hour should be got out of her. In fact, to keep down her cost, to render her quick in evolution, and easily handled in our rivers, her length cannot well exceed the limit indicated of 280 feet. Her maximum draught should not pass beyond 18 feet, if she is to go easily over the bars at the mouths of most large streams, and penetrate well up into them; and also navigate if necessary along our coast in depths unsuitable for other war vessels of greater draught. The foregoing moderate draught possesses this advantage too; she can approach close to shore toward a fortified point which she intends to attack. Smaller than 18 feet her draught cannot well be made, considering the load of armament, armor, coal and engines which she will have to carry. Still, if it could be reduced to 16 feet, her efficiency as a ram and as a cruiser along our coast, would be considerably augmented. In order that she may set in the water with stability, and present a steady deck with necessary room below, her greatest width of beam, measured at the water line, should be some 45 or 46 feet. A greater width would interfere with her having suitable lines for her speed, and a lesser one would not give her enough deck room, as well as buoyancy. An armored vessel carrying heavy artillery, large amounts of coal and ammunition, many boilers and heavy engines, cannot have the fine lines of a race boat, without sacrificing in her considerable buoyancy and stability; although her armor and artillery be reduced so as to become comparatively light. Her bow and stern may be designed moderately sharp; this feature will not prevent her maximum width from being carried some considerable distance along her sides before it is materially diminished. Stability and diminution of draught are secured at the same time by means of full sections and a rather flat bottom amidships. We may reasonably count upon her extra strong engines counterbalancing to a certain extent want of fineness in her lines; but her extreme breadth cannot be greater than one-sixth of her length, and her maximum draught more than 18 feet, without taxing too much her engines.

She should lie as much as possible under water, which element is the best protection she can have against the shot of an enemy. Therefore her deck, when she has everything aboard, should not rise more than 4 feet above her line of floatation. If circumstances permit it she ought to sink herself a foot lower still with water when she prepares for action. She will expose in all cases only a narrow strip of her hull to fire; and, being of moderate draught, considerable beam, and not great weight, she will be able to ride easily a heavy sea, and keep her deck quite dry in bad weather. As she is nevertheless exposed to ship heavy seas, plenty of outlets well protected are required in her sides to let the water escape quickly. She will possess a steadier deck, and require much less armor plating than if she rose 7 or 8 feet out of water; the former is a matter of some importance as regards accurate firing from a vessel. A low broad-side, with no houses on deck, make a ship present small surface to the wind, and gives her better sea-going qualities, as well as subjects her to less retardation in her speed under adverse circumstances of wind and waves. Her bulwarks are not to be pierced with any port-holes; they are to rise some 4 feet above her deck; her guns will fire over her bulwarks and be elevated therefore between 8 and 9 feet above the water. Although this height is not sufficient generally for long range firing, yet an advantage of this nature may well be sacrificed in this instance, considering that she is a vessel intended to fight at close quarters.

Commencing at about a foot below her highest water-line, her sides should run up perfectly straight to the top of her bulwarks, falling inward from the vertical some 30° or 32°; which inclination is to be carried along both boards of the ship to within a proper distance of her ends, when it should begin to diminish gradually until her sides become perfectly vertical at her bow and stern. No material interference evidently will occur with her lines below her plane of floatation; and they may be designed the same as though her sides were of the usual shape. Her buoyancy, however, will be increased at her ends with nearly vertical sides there running for some distance back.

Opposite to her engines her armor may be 5 inches thick; over other parts of her hull it may descend to 4, except for some 25 or 30 feet along her bows and stern, where it may be only 3 inches. It should not pass above her deck, except where her guns are located; at which points it may reach to the top of her bulwarks, extend for a few feet on each side of the guns, in order to protect their carriages, and have its thickness augmented an inch or so. Thus arranged the chances for shots which strike her sides below the deck glancing off are greatly increased. By swinging over her sides her chain cables as armor when she goes into action, she is still in better trim for defending herself by deflecting shots. Some deck-room will have to be sacrificed to the foregoing disposition of her sides, and some head-room below also; but these disadvantages are not great. Her armor and guns, on the other hand, will be put nearer the center of the ship, and she will have more stability in the water, with a steadier deck from which to fire. The bulwarks should be thick enough to prevent the bullets of Gatling guns from going through them. At some 30 or 35 feet from the end of the bows, inclined armored defences 4 feet high, should be run obliquely across the deck from both bulwarks, to meet in its center. In the angular space so formed should be put one, or better, two heavy guns, the carriages of which will be protected by armor plating on the defences in front, and on the bulwarks at the sides. The same arrangement should be introduced at the other end of the ship. Forward of the bow guns the bulwarks should rise about 6 feet above the deck, and be made removable; so that when the vessel goes into action, these guns won't blow them away and tear up the deck ahead. At the stern similar bulwarks are needed, but not rising so high by 2 feet. A battery of 8 or 10 comparatively small guns should be carried along her broadsides. Around her masts, and on light open-work bridges reaching across the deck at an elevation of 12 feet, and, supported at their center and ends, should be placed a dozen or more Gatling guns.

Several advantages are connected with putting her heavy guns at her bow and stern. In whatever position relatively to herself lies the enemy, she can always bring at least half of these guns to bear on him, and when chased also she can utilize them. When, on the contrary, she assumes the aggressive, being essentially a ram, she will approach close to her adversary, and fight with her bows toward him; in order to ram at the first favorable opportunity, while she is using in the meantime her most effective guns on him. Her broadsides are her weak spots; these she should expose as little as possible to a floating enemy; but her bows and stern, if only moderately sharp, will be well shaped for deflecting shots. However, to prevent the possibility of a very heavy shot entering her bows below the deck and passing nearly or entirely through her hull lengthwise, a couple of bulk heads a certain distance apart, inclined, covered each from about the water line to under the deck with 3 or 4 inches of plating, and located under her bow guns, may prove efficacious. In fighting a fortification, or shore battery, she will present her broadsides, and run the risk, perhaps, of having a heavy shot sent into her engine room; but she is none the less able to continue fighting if her guns are not dismounted, and she does not make water at every point.

Her deck should be level from stem to stern, and properly shaped in plan fore and aft; where it should present width enough for her heavy guns. It should be capable of being made tight over all openings, and should be encumbered as little as possible with projections. Light and air will have to pass down through apertures in it. In time of peace a man-of-war is made to proceed as much as possible under sail, consequently heavy rigging is usually carried; but in case of war, a vessel, such as we have described, should have her rigging changed, and diminished to the minimum amount, as she will then steam entirely, and will not want to have her deck encumbered during an action with the debris of rigging. Her deck lying low, she will not, under any circumstances, be able to carry much sail; in fact, she is designed as a steamer, pure and simple, availing herself slightly only of wind power, but amply provided with coal space.

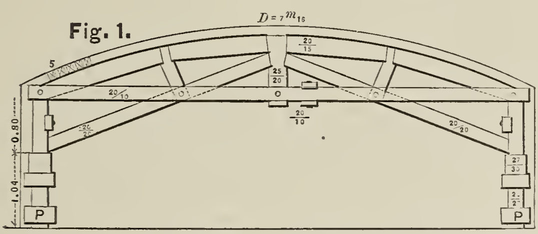
A NEW METHOD OF DECENTRING.

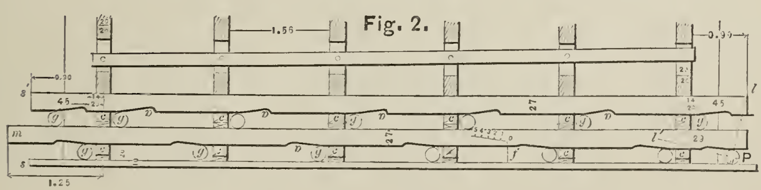
By M. HENRY.

Translated from "Annales des Ponts et Chaussées" for VAN NOSTRAND'S MAGAZINE.

THE system of decentring by means of rollers has for its object the substitution of rolling friction in place of the sliding friction of the wedges or ratchets which are sometimes employed in decentering arches; and, furthermore, to employ a method which may be used in the water.

The following illustrations will suffice to give a complete description of the construction and method of working of the apparatus employed:





Between the lower sill s and the upper one s' of the center, and on each side of the arch are placed two series of rollers g, g, g . . . . . separated each from the other by a key or movable block m, which can be moved in a direction lengthwise of the arch, and confines the rollers in their inclined notches v,v,v......

The wedges c, c, c, placed between the sills are designed to relieve the rollers and to afford increased stability to the system during construction.

Two levers working over the rollers P, P, P, placed at the head of the arch at one end of one of the series of rollers, serve to overcome the resistance to starting, and to facilitate the movement or to retard it as the case may be during its course.

Marks *f f*, upon the lower sill corresponding to similar marks numbered

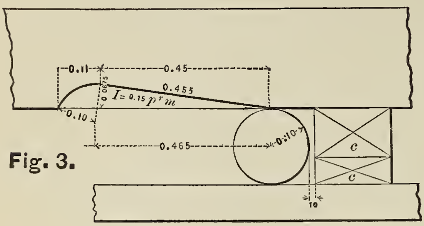


Fig. 3.

upon each of the movable sills, serve to indicate the progress of decentring.

The radius of the rollers being $0^m.10$, and the slope of the notches in which they roll being $0^m.15$ per meter, it is seen that three quarters of a revolution (or even a little less than this) of the rollers leads to a lowering of $0.0675 \times 2 = 0.135$. The drop of the center would evidently be $0.0675 \times 3 = 0.2025$ if the notches of the same form and arrangement were in the lower sill.

In case the levers were insufficient to start the centering, or, what is the same thing, in case the resistance to rolling friction of the four series of ordinary rollers is greater than the resistance to the sliding of the two traveling rollers, recourse must be had to jacks. The levers would then be employed to continue the motion started by the jacks, and to regulate the movement of the rollers.

This system of decentring was first employed in 1875 by M. Chadard, engineer in charge of the highways of the *arrondisement* of Clamecy.

We had the honor of introducing the plan to his notice, on the occasion of building an oblique bridge under his direction across the river Chalaux, near Lormes.

The rise of the arch was $2^m.65$ under the keystone. The span was 6 meters and the angle of skew 60°. The decentring was accomplished in the water.

The following extract is from a letter from M. Chadard to M. Chatoney, inspector of bridges and highways:

"I would advise the adoption of very low inclinations for the slopes of the sills which enclose a series of rollers. At Chalaux this inclination was too great, and with a very slight effort the decentring proceeded much too rapidly. The question must be decided by experiment, for I must confess that the conclusions derived from my calculations were not verified. It is reasonable to suppose that the inclination in question should vary in some way with the weight of the framing, or better perhaps that the notch should present a curved form approaching the cycloid, instead of an inclined plane. Be that as it may, however, notwithstanding the difficulties of a first trial, I have good reason to be satisfied with my experience, and I am convinced that under conditions analogous to those I encountered, the system of rollers is capable of rendering good service."

Steel Plates for American War-Ships.—A Washington special says:—"Several members of the House Naval Committee have been considering the question of the substitution of steel for iron in the construction of armored ships of war. Having obtained considerable information on this subject, they are desirous of getting this before the full committee, and at their next meeting the matter will be formally brought up and considered. Mr. McKay, a ship builder, and others from Boston and New York, will appear, and submit to the committee the results of the experiments in England and Germany, showing that the maritime Powers of Europe have abandoned the use of iron for armor plates, substituting steel, as it is found by actual test that five inches of compound steel plate will afford a resistance equal to ten inches of iron. It has been suggested to the committee that the subject had better be thoroughly examined before reporting the appropriation asked by the Secretary of the Navy for the completion of the four "ironclads" authorized by Act of Congress. The Secretary of the Navy is also considering this matter, and expects shortly to forward to the committee the result of his investigations.—*Iron*.

RAILROAD SIGNALS.*

BLOCK AND INTERLOCKING SYSTEM.

There can be no doubt that, for security from rear collisions, and from accidents occurring by reason of misplaced switches, or open draw-bridges, the block system, carried out by interlocking switches and signals, comes nearer to insuring immunity from accident, than any other known device. The block system, long used in England, and now brought almost to perfection by interlocking devices, is so called because under it each section of road is "blocked" by signals against the entrance of a train, while that section is occupied by another train. Improving on the former system, which only provided for an interval of time between successive trains, the block system secured an interval of space. Under it a railroad was divided into telegraphic sections. Before a train could start from the first station, a signal was sent from the first to the second, and a favorable reply was received; then a signal was made for the train to leave station one, and at the same time station two was notified of the fact; this notification was acknowledged, and the section was "blocked" by a signal showing that it was occupied. When the train reached station two, a signal was sent to station one that the line was clear, and the "block" was taken off. Of course, if the train met with an accident, or if it was delayed in reaching the second station, the section continued to be blocked; and no other train entered it until a signal from the second station gave notice that the danger had ceased. And the same precautions guarded every section throughout the line.

THE INTERLOCKING OF SWITCHES AND SIGNALS, combined with the block system, not only secures each section from the entrance of a train while it is already occupied, but also blocks the section for any train while the track is broken by the throwing of a switch, or by the opening of a drawbridge, thus removing these causes of numerous disasters, while it allows a vast increase in the number of trains.

The method in brief, is by the use of levers operating switches and signals so interlocked that a signal of safety cannot be given while danger exists, and danger cannot exist until after it has been signaled. In other words, the operator cannot, by negligence or forgetfulness, or even from malice, create a danger, or suffer it to exist, until he has signaled it afar off, to any approaching train. He cannot open a switch before setting a signal at danger; having opened a switch, he cannot leave a signal at safety; he cannot set the signal at safety before closing the switch; he cannot leave the switch half closed without giving a signal of danger. All these four errors, each of which has cost many lives, are made impossible in a section of road guarded by this system. And the boast is not extravagant, that for this purpose, the working of signals is not trusted to the intelligence, or to the fidelity of a man, but that each man becomes part of an unerring machine, in which his will ceases to operate, and he must act in accordance with the principles of its mechanism.

Mr. Barry, in his work on railway appliances, gives a strong illustration of the perfection to which mechanical provisions for safety have been carried. At Cannon-street station in London, seventy switch and signal levers are placed in one signal house, making millions of combinations possible, if they were not interlocked. Of these combinations only eight hundred and eight are safe. Yet a stranger, blindfolded or blind, handling these levers at random, cannot produce a condition of danger. He could stop trains and hinder business, but he could not create a possibility of danger without signaling it in advance.

More than this—because the pulling of the wrong levers, although not causing immediate accidents, does strain the machine, and thus might lead to unlocking of the levers, with consequent disaster; therefore, the attempt and bare

* Abstract from the Eleventh Annual Report of the Railroad Commissioners of Massachusetts.

idea of pulling the wrong lever is checked by mechanical means, and the uncertain will of man is subordinated to the perfect mechanism of this device.

In operating this apparatus two systems of signals are used, one near the cabin or tower of the operator, and one at a distance sufficient to enable a train to be stopped after the signal is seen, and before entering on the blocked section. The semaphore is used by day for a signal, as being the one distinguishable at a greater distance than any other form. At night, colored lights are used. Mechanical means may be employed for short distances; electricity serves for long distances. To supplement the signal, if it should be obscured by fog or darkness, a "contact bar" is sometimes used, which, with the danger signal, assumes a horizontal position, and by striking the cab of the locomotive gives a warning somewhat like that given by the bridge-guards which strike the person who is exposed on a freight car.

The working of this system for drawbridges is the same as for switches. The draw cannot be opened until the signal for danger has been set. The signal of safety cannot be given until the draw has been closed and actually locked.

By uniting the interlocking device with the block system it becomes impossible to telegraph safety from one signal station to the station next in the rear, until all the switches are in a safe position for a coming train. It is impossible to move switches so as to allow access from a siding to a track which has been telegraphed as safe for a coming train. It is impossible to so move the switches, or any one of them, after the line has been telegraphed to be blocked. It is impossible for a train to enter a section until its coming has been announced by telegraph, for the signal to enter cannot be given until a signal announcing its approach has been received. The signal which permits entrance into a section cannot be given without the concurrence of signal-men at both ends of the section. The starting signal is reset at danger by machinery behind every train. The signal that the line is blocked must be given from the station in advance to the station in the rear.

This summary, in substance, is borrowed from a description of the combination of the Toucey and Buchanan with the Saxby and Farmer devices, which, aided by some subsidiary inventions, are now in use on a portion of the Pennsylvania Railroad, and on the Metropolitan Elevated Railroad in New York, as well as elsewhere.

The ingenious device of David Rousseau, involving the same principles, and accomplishing the same end, may be seen at the New York Grand Central Depot. The members of the Board have seen the operation of these inventions at these points; and their daily working vindicates the high claim made on their behalf. It will be a happy day for travelers when this system, in all its completeness, has been universally adopted on American railroads.

But the block system, as operated with interlocking devices in England and France, and as used with additional improvements on portions of American roads, requires a large body of skilled and well-paid men. For an unskilled operator, although he could not cause danger, would cause delay and difficulty. Our inventors, therefore, have tried to supply its place by automatic signals, guarding a road and giving warning of danger, without the constant intervention of man. And it is claimed by some of them that their inventions are not only more economical than the English system, but that they are safer. In the language of one of these inventors: "My device is better than a man, for it is always on hand; it never sleeps, and it never drinks."

As a preliminary remark to a discussion of automatic signals, it may be observed that it is a requisite of any system that the normal condition of its signals should indicate danger, so that in case of any derangement of apparatus, accidental or intentional, warning will be given. Thus, failure to act will at most stop or check the movement of a train. It will never cause a disaster. A device that fails in this particular, fails at the outset. It is, also, absolutely requisite that the danger signal should be given far in advance of the point of danger. A signal displayed at or near the point of danger is utterly insufficient and unsatisfactory.

HALL'S ELECTRIC SIGNAL

is the best known and most widely used. He employs an open circuit; and the current which keeps his signals set at safety is transmitted over wires. This current being broken by an engine entering a section and touching a circuit closer, sets the signal at danger.

1. As a safeguard from rear collision, theoretically at least, it approaches perfection. The danger signals are set a mile or less apart, and a red disk shows that a section is occupied. A secondary signal, sometimes called a tell-tale, is placed a thousand feet in advance of the danger signal, and informs the engineer whether the danger signal behind him has been set. When the engine passes out of a section, it sets the signal of safety for that section. If the current ceases to work from any cause, a signal of danger will be given. But absolute perfection has not yet been obtained in the construction of the apparatus; and the passage of a train sometimes fails to set the signal of danger; yet, in that case, the tell-tale will indicate danger. And so it cannot happen that both signals belonging to a pair will indicate safety when danger ought to be announced.

2. Station agents, by a separate device, can arrest the progress of a train at a distance of half a mile by a signal of danger.

3. The connection of switches with this system makes it impossible to open a switch so connected without blocking the track by a signal. This occurs at a distance of two thousand feet, more or less; and at the same time a bell rings at the switch, and continues to ring until the switch is closed.

4. The application of this system to draw-bridges appears to secure perfect safety. It is impossible to open a draw-bridge without blocking the track by a distant signal; and if the engineer fails to see, or recklessly disregards the blocking signal, then another signal will arrest his progress—a mechanical drop constructed of heavy plank, placed two thousand feet from the draw, and so arranged that it falls by gravity when the draw is opened; and if the engineer still presses on, his locomotive is sure to lose its smoke-stack, and he yet has time to check his train and escape disaster. The working of this device was curiously illustrated when it was first used on a road in New York; for the train-men, having a prejudice against it, as a novelty, determined to disregard it; and more than one engineer bringing in his locomotive without a smoke-stack, gave the best evidence of his own recklessness and of the merits of the invention. Now, that draw is opened one hundred and thirty times a day, and it is approached without fear of accident. Two other adjuncts furnish additional safeguards in approaching a draw-bridge guarded by Hall's signals—a bell ringing at a distance of a mile when the draw-bridge is opened, and a signal given to the bridge-tender if the train enters the blocked section.

5. The notice given to passengers and agents at stations, by bells differing in tone for "up" and "down" trains, announcing the approach of a train is convenient, and tends to prevent accidents. For its purpose it is a perfect device, while it saves the great annoyance of whistling.

6. Highway crossings at grade are guarded by a bell, or gong, placed at the crossing, which begins to ring when a train approaches within half a mile, and continues to sound until the train has passed. This calls the attention of the flagman or gatekeeper to his duty. And if the sound were loud enough, it would arrest the attention of travelers, and warn them of the coming danger. Some device of this kind has been heretofore urged by this Board; and their views are repeated in their report on the Lincoln accident. With such an appliance, giving an alarm sufficient to command attention and always in working order, there would be absolutely no excuse for an accident at a crossing, unless it happended to a man blind as well as deaf; for not only does the bell sound, but a signal to stop is displayed to the eye automatically while the danger continues.

But such a device, in order to be depended upon, must be without the possibility of failure; and neither in theory nor in practice can this be said of Mr. Hall's crossing signal. The ringing is done by the positive aetion of electricity put in operation by the passing of a train. If the apparatus is out of order no current is produced and no warning is given. The principle that danger should be indicated unless something positive happens to prevent it, is not carried out in this part of Mr. Hall's invention. And, in fact, we learn that such an apparatus, placed within the limits of Boston, does occasionally fail to announce a coming train. Its use, therefore, is only auxiliary; and it will not, as it now exists, allow railroad managers to dispense with other safeguards at highway crossings.

The objections urged against Mr. Hall's block or track and switch signals, apart from their cost, are mainly these:

(1.) It is said that they are so delicate and complicated, that they often fail. This, to be sure, when the failure is of electric current, does not directly result in an accident. It only delays a train. Each double-track road has orders directing the time of delay on seeing the signal of danger; a time necessarily brief—say one minute—and after this the train proceeds "with caution." But the tendency of frequent false alarms is to reduce the amount of caution; and the cry of "wolf," too often repeated, may make it unavailing when danger really comes.

(2.) It gives no warning of a broken rail, and does not profess to give such warning.

(3.) Neither does it give warning of a car left on the track by a passing train —an accident not unusual, especially with freight trains. On the contrary, in such a case, the engine with the portion of a train attached to it, passing off from the obstructed section, sets the signal of safety, and lures a coming train into danger by a false announcement. Something like this happened recently on one of our Massachusetts roads. An engine was sent after dark to take five cars from a siding, push them on the main track, and then haul them away. There proved to be six cars which were pushed from the siding, and when the five were hauled away, one uncoupled car remained on the main track. A passenger train afterwards left the station and came in collision with this car. Fortunately, the result was not serious, but it illustrates a danger against which Mr. Hall's signals do not profess to guard.

(4.) So it is said that a train on a guarded section, followed by another train proceeding with caution, would, on passing off, set the signal of safety. The second train breaking down, from some defect of wheel or like cause, would remain as an obstacle and possible cause of collision with a third train coming on the section with the assurance of a clear track given by the signal. This, however, could never occur unless the second train were allowed to enter a blocked section, nor without gross carelessness on the part of those in charge of that train in neglecting to flag the section.

THE UNION ELECTRIC SIGNAL,

hitherto little tried in actual working, professes to do away with all these objections, and to guard against all the dangers which Mr. Hall leaves unguarded. Its fundamental difference from his system is, that it uses a closed circuit, with an electric current moving through the rails; and this current holds the signal at safety, from which it is moved to danger by mechanical means, whenever the current is checked, whether by the dangers intended to be guarded against, or by some accident to the apparatus. Thus, in all its operations (as in most of Mr. Hall's) a failure to work gives warning of danger, but no failure can entice a train into peril. The circuit through the rails is made more effective by wires connecting each rail with the next and firmly fastened at every joint. This was found necessary because the oxidization of the rails interrupted their conducting power. Each section is insulated by the use of vulcanized fibre. This seems to be effectual. The mechanical means by which the signal is given, in case of a broken current, is a simple clock weight so arranged that it runs for several days, giving passage for six hundred trains before it runs down. The current is produced by a battery; and in cold weather a kerosene lamp, burning for a week at a time, is used to keep the liquid from freezing.

When a section of road is guarded by this device, the entrance of a locomotive breaks the current simply by placing its wheels upon the conducting rails; and thereupon visible signals of danger are given, and when the train approaches a station or crossing a warning bell is rung. So excellent is its working, that a piece of wire laid across the rails breaks the current and sets the signal of danger; and a stray goat, dragging his chain after him across the track of the Providence Railroad recently, gave the alarm as of a coming train to the gate man at Forest Hills crossing. A secondary, or tell-tale signal, in this system informs the engineer at once whether or not his train has given warning. And station agents have the means of warning a train that is entering on a blocked track. This device is considerably cheaper than Mr. Hall's; and it is claimed, that, being simpler, it is less likely to be out of order. But it certainly has these more important advantages:

(1.) As a crossing signal it indicates danger in case of any accident to the apparatus. The failure of a battery, the breaking of the apparatus by accident or design, would of itself give an alarm, while in such case, as has been said, the Hall device would cease to work, and trains would pass without warning. It is claimed, also, that it has this incidental advantage: under it the bell is sounded by mechanical means, which are released by breaking the electrical current. And so the ringing may be done more powerfully than when it was effected by the direct power of electricity, which is varible, and which, as practically used, is supposed to be feebler than the cheap mechanical power applied by clock motion. But the soundness of this claim has not been demonstrated by any exhibition made to this Board. And no crossing signal of this system has yet been exhibited which seems calculated to arrest the traveler's attention, as thoroughly and certainly as it should.

(2.) The breaking or displacement of a rail, by interrupting the current of electricity, gives a signal of danger, provided the displacement of the portions of the rail is sufficient to cause such interruption.

(3.) It indicates the presence of a car on the track by whatever means it came there.

The invention has not been used nearly as much as Mr. Hall's. Its proprietors, therefore, cannot refer to so many witnesses as to its working. Probably it is just to add that, for the same reason, there may have been fewer criticisms on its defects. As has been suggested before, there seems to be this advantage in using a closed circuit, that it requires less from electricity. The labor of this system is done by gravitation, and electric force is only used to control it. Electricians are accustomed to say—"The less you ask of electricity the more sure you are to get what you want." In the present state of science this is no doubt true.

Among the possibilities of failure with this signal, is neglect to wind up the weight, which would prevent any signal from being given. Some also object to the need of lighted lamps in cold weather; but failure of a lamp, resulting in the failure of a battery, would set a signal of danger. On one road, where a few of these signals are used, frequent breaking of the wires is complained of as giving needless signals of danger. The Fitchburg Railroad Company has had the signal on five miles of its road for more than a year, including the whole of last winter. Since May it has been in charge of the officials of the road, and their report is highly favorable. If it works well through the winter, it will have had that full and continued testing which such inventions need before they can be commended with entire confidence.

ROSSEAU'S SAFETY RAILWAY SIGNAL.

This signal has already been referred to as used in blocking the New York Central and Hudson River Railroad, where it has been in successful operation for nearly four years. It resembles Hall's system in many points—among others, in using an open circuit. It resembles the Union Electric Signal in using gravitation as the power which actually gives the signals, thus requiring a less powerful battery than the devices where electricity does the direct work. The signal is set by a clock-weight; and when wound up, it signals three hundred and fifty trains before it needs winding again. By an ingenious device the lamp on these signals cannot be removed for trimming without winding up the weight

As in the inventions described before, the engine, when it enters a section, sets the signal at red, meaning danger, and it so continues until the train has passed off, when it sets it at clear, meaning safety. Each of these effects is produced by a "commutator" over which the wheels pass. In places of extra hazard, two danger signals are used—one called a distance or cautionary signal, a thousand feet in advance of the signal within the section that is to be entered. If this distance signal shows green (or any color selected for the purpose) it indicates that the second signal is red, and that the engineer must stop before entering on that blocked section. This system also provides each station master with the means of stopping any approaching train if danger has been shown to exist; and an indicator keeps him acquainted with every movement on his section of the road. An extra signal, to be used in foggy weather or in dark tunnels, is a rod, which not only strikes the engine, but by an additional device causes the whistle to sound; and it is said it can be applied to the brake, and made to stop the train. The long use of this signal in the Harlem Tunnel is relied on as proof of its excellence. The application of the system to switches and draw-bridges needs no explanation. And the application of all these systems to a single track, while it presents points of difficulty, is a matter of detail which need not be discussed.

BEAN'S ATMOSPHERIC SIGNAL

is a safeguard against the dangers arising from open switches and draw-bridges; and it is also applicable to stations and crossings. The Old Colony Road has tested this device by using it at exposed points for more than two years, gradually increasing the number of instruments in use, and now having them working at distances varying from a thousand to two thousand four hundred feet at one drawbridge, two stations, and several switches. This signal is simple and inexpensive; and, so far as it has been used, and for what it undertakes to accomplish, it seems to be an almost faultness device.

In conclusion, it is evident that the time has not come when the adoption of any one of the devices exhibited for giving automatic signals should be required by law. No party has asked for legislation; and Mr. Hall strongly disclaims any desire for legislative action. Nor, pending further experience on the part of railroad men, and further experiments by electricians and other inventors, can it be thought strange that railroad companies hesitate to equip their roads fully with imperfect devices, which may soon be set aside for better. Many ingenious men are giving their thoughts to railroad signals. The laws of the force, which most of them are trying to use, are not fully known, and the force is not capable of entire control. The railroad managers of England, and, indeed, of Europe, are more than skeptical as to the use of automatic signals, electric or otherwise. They would regard reliance upon such signals as criminal recklessness, if they were not supplemented by other appliances. Many railroad men in this country share this feeling; and this refers not only to railroad managers, who might be suspected of being influenced by undue economy, but to skilled superintendents and other experts who have no such motive. At present no one has the the right to say of any system of signals as a whole: "This is the system that ought to be adopted on all roads." The desire is natural that some tribunal should decide at once which is the best, and that the legislature should order its adoption. But the time for such a decision has not yet come, even if any automatic device can ever be found which will alone answer all the purposes of a railroad safety signal.

Yet it should be remembered that these imperfect devices do render great service in announcing danger and preventing accidents. The worth of a safety signal is to be estimated chiefly, not by counting the number of its false alarms, but by its well-founded alarms. Even an occasional failure to give warning of danger, while it forbids sole and implicit reliance upon an automatic signal, does not prevent its being of great value as an auxiliary. When the terrible consequences of a railroad disaster are considered, a preventable accident becomes a crime. The public have a right to expect that their safety will be guarded by every reasonable precaution, and that devices designed for this end should not be rejected simply because they have not attained perfection. Railroad managers should be quick to guard their tracks, and especially all draw-bridges and other points of special danger, by those appliances, that seem to them best adapted to insure safety. It is proper to add that our chief railroad companies have shown a praiseworthy spirit, both in testing new inventions, and in adopting those, that, upon trial, have commended themselves to their judgment.

PORTLAND CEMENT.

By HENRY FAIJA, Assoc. M. Inst. C. E.

From "The Building News."

I BELIEVE it is some forty years since Professor Donaldson made some very interesting and exhaustive experiments with Roman cement and with the septaria from which that cement is made. Roman cement was then employed in almost every building of importance, while what is known as Portland cement had scarcely emerged from the laboratory and was practically unknown. The introduction of this then new cement, it is needless to say, was met on all sides with great opposition, but its eminently hydraulic properties and great strength eventually asserted themselves, until at the present time Portland cement is synonymous with strength. But, like all manufactures which assume large proportions, there are unfortunately both good and inferior cements to be met with; and as the strength of a concrete or mortar must depend not only on the quality and properties, size and shape of its aggregates, and the means employed for their amalgamation, but also on the strength and quality of the cement, I propose in this paper to speak solely of the primary source of strength, viz., the cement. The recognized tests for Portland cement, are its weight per striked bushel; the fineness to which it is ground; its color, and its tensile strength. With the exception of the tensile strength, which is an absolute test, these tests are really only problematical, for it is evidently possible to obtain a material that, in weight, color, and fineness, may approximate to the standard required in Portland cement, and yet not be cement. Hence a bad or a damaged cement may possess all these requisite qualities and yet fail in the crucial test of strength. It is also possible, but in a minor degree, to have a cement that is of the required strength, but would yet fail to give the results expected of it, when made into concrete or mortar. From experiments extending over a considerable period, the results of which are given in the accompanying tables, I hope to be able by (1) determining the work which a cement has to do, and (2) by considering separately the properties which it should possess to attain that object, to arrive at such results as will be of value to both users and manufaturers. Concrete or mortar, being a combination of aggregates which are united into a compact mass by means of the cement, it follows:—that the cement should possess strength; that it should be so finely ground as to thoroughly intermingle with and separate all the aggregates used, thus cementitiously uniting each particle; that it should set fairly quickly, and that it should neither expand nor contract during setting. Without describing the manufacture of cement, which is carried out in various ways according to the nature of the raw materials used, it may be considered, for the purposes of this paper, a combination of carbonate of lime, silica, and alumina in certain proportions. These ingredients are obtained in different localities in various forms. Thus, on the Thames, the white chalk, which is nearly a pure carbonate of lime, is used in combination with Medway mud, which contains the silica and alumina. In many works on the Medway the grey chalk is substituted for the white, and Gault clay is used instead of the Medway mud. At Folkstone and other places on the South coast, similar materials are used. At Harwich, Newcastle-on-Tyne and Stockton-on-Tees, a local blue clay which contains the requisite proportions of silica and alumina is used in combination with chalk, which is imported generally from the Thames. In the North of France—in the neighborhood of Neufchatel and Devres—a natural cement earth is found, generally at the foot of the chalk hills. This material, which much resembles grey chalk in appearance, contains, in many instances, the exact proportions of lime, silica, and alumina for th · production of a high-class cement. At Rugby, in Somersetshire, and other parts of England, the blue lias formation supplies the requisite ingredients, the stone and clay being found in layers of from a few inches to as many feet in thickness, one above the other. At Madras, a cement is made from lime produced from sea-shells, used in combination with a river mud, and I have lately been consulted respecting the manufacture of cement from somewhat similar materials, viz: coral lime and a river mud, found on the opposite side of India. At Rio de Janeiro also similar raw materials are used. In Derbyshire, the immense limestone hills may be made available for conversion into cement, in combination with a tufa which is also found in the locality. In Buckinghamshire, on an estate on which I am at present engaged, there has been found a deposit of a natural cement-earth, which lies immediately under the surface and averages about 10 ft. in thickness, lying directly on the Oxford clay; with it is intermingled a considerable quantity of a nodular limestone. It would be needless to enter more fully into the geology of Portland cement manufacture, but it may be taken that wherever carbonate of lime, silica, and alumina are met with, in a fairly-easy convertible form, there Portland cement can be made. But with each variety of material different means must be employed for attaining the desired end; and to describe the process of manufacture in each case would take up more time than is at our disposal. The process may, however, briefly be divided into three stages, viz:—the thorough mechanical combination of the raw materials, their calcination, and the reduction of the clinker by grinding to the Portland cement of commerce. From this very cursory glance at the materials from which Portland cement can be made and the mode of manufacture, it will readily be seen that there are many causes which may materially affect the result of the cement produced, viz: the quality of the raw materials themselves, their amalgamation in correct proportions, their perfect mechanical combination, the proper calcination of the combination, the perfect reduction of the clinker to a fine powder, and lastly the careful storage and cooling of the cement before it is used. Of the causes of many of the results which may be met with, it is impossible to more than allude to, but assuming that the raw materials have been well chosen, an imperfect amalgamation of them will probably produce a blowing cement. The use of an undue quantity of lime will produce the same result, combined with slow-setting powers, while the use of too much clay will produce a quick-setting cement, that will contract. Having secured the perfect amalgamation of the raw materials in the proper proportions, similar results may be obtained from imperfect calcination, thus a lightly burned cement will be quick-setting, and an overburned cement slow. Having regard, therefore, to the number and combination of circumstances which present themselves for consideration, when it is required to divine the causes which produce certain results, I propose to treat solely with the peculiarities and properties which developed themselves during the experiments made with certain samples of cement, and to deduce from these results certain data which may be of service in judging of the quality of a cement for the purposes for which it is required. The quality usually required of cement is in accordance with the standard set out by the Metropolitan Board of Works in the regulations relating to concrete buildings, viz: That "the Portland cement shall be of the very best quality, ground extremely fine, and weighing not less than 112 lbs. to the striked bushel, and capable of maintaining a breaking weight of 350 lbs. per square inch, after being made in a mould and immersed in water during the interval of seven days." It must be admitted that, taken as a specification for cement, this regulation is rather vague, and as in all matters appertaining to the testing of cement great exactness is required, and that a uniform and standard apparatus should if possible be adopted, I think that the Metropolitan Board of Works have it in their power, by somewhat enlarging on this regulation, to lead to the abolition of many abuses, and thus tend to the elucidation of many seeming contradictory results.

As the weight per striked bushel of a cement must evidently vary according to the means employed to fill the measure, it is essential that it should always be filled in the same manner. The apparatus which I use, and which I think meets all requirements, consists of a circular iron hopper or funnel perfectly smooth on the inside, into which the cement to be weighed is placed; at the small end it has a canvas stocking, which leads the cement into the zinc shoot, placed at an angle of 55°, the lower end of the shoot being five inches above the top of the measure. The measure, placed on a perfectly firm floor, on which there is no vibration, is never in any way touched during the process of filling, nor until after it has been carefully struck with a straight edge. When filling the measure the stocking may be held in the hand so as to regulate the run of the cement from the funnel. In a paper I read before the Institution of Mechanical Engineers, in Jan. 1875, when referring to the weight of cement, I said: A light cement is generally a weak one, though it may be of the requisite fineness; at the same time, a heavy cement if coarsely ground is also weak, and will have no carrying capacity for sand. As the more the clinker is burned the harder and heavier it becomes, and therefore more difficult to grind in the millstones, the heavy cements to be met with are almost invariably coarse ones; and as an underburned cement, from its softness, will be ground fine enough, but will be found deficient in weight, so it will be seen that the weight, unless taken in conjunction with the fineness, is no test as to the quality of the cement." This opinion I have found confirmed by subsequent experiments, the results of some of which are given in Table No. I. In each case the cement was weighed, tested as delivered, and also when ground; so that all would pass through a No. 50 sieve. The tensile strengths given being in each case an average of ten briquettes.

Table I.

	Residue per cent. after sifting through sieve having 2,500 meshes per square inch.	Weight per striked bushel.	Tensile strength on section 1 inch square. 7 days.	Tensile strength on section 1 inch square. 28 days.
No. 1—			lb.	lb.
Cement as delivered from manufactory	25	114	535	661
Cement ground to all pass sieve 2,500 meshes ..	Nil	104	572	not taken
No. 2—				
Cement as delivered	16	116	509	650
" ground..	Nil	109	542	675
No. 3.				
Cement as delivered	14	116½	476	662
" ground..	Nil	112	505	710
No. 4—				
Cement as delivered	33	118½	693	728
" ground..	Nil	105	666	810

By examining these results, we find, firstly, that by fine grinding the weight per striked bushel is reduced, and secondly, that the tensile strength is increased, both at the expiration of seven and twenty-eight days from the time of gauging. That the weight per bushel should be less, is what would naturally be expected, as it is evident that the finer particles are less dense than the coarse, and also that they fall lighter into the measure. That the fineness to which a cement is ground should affect the tensile strength in so marked a degree, may be accounted for by the fact that the coarse particles in a cement have practically no cementitious property, being little better than so much sand. To prove this the following experiments were made with the core or coarse particles in a cement:—1. The residue that would not pass through a 625 mesh sieve was gauged with water, and, at the expiration of seven days, was found to be merely held together in a mass similar to so much sand, having a slight admixture of loam. 2. That which passed through the 625 mesh sieve, but would not pass through the 2,500 mesh sieve, was gauged in a similar manner, and at the expiration of the same time was found to be in a similar condition. 3. That which passed through the 2,500 mesh sieve, but would not pass through a 4,900 mesh sieve, being gauged in the same manner, was at the expiration of the same time found to be in a similar condition. These experiments were made with a cement that was perfectly set in thirty minutes after gauging. In each of these cases the pats could be crumbled to pieces between the finger and thumb, and the granulations were the same in size and shape as before the water was put to them, thereby proving that the granulations themselves had no power of setting, but were simply held together by the infinitesimal particles of finely-ground cement, from which it was impossible to separate them. It, therefore, seems that the granular portion, or the core of a cement, has really a deleterious effect on its strength, and for all practical purposes may be considered only as so much sand.

Table II.

	Sample No. 1.		Sample No. 2.		Sample No. 3.	
	7 Days.	28 Days.	7 Days.	28 Days.	7 Days.	28 Days.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Cement as delivered from Works.. ..	535	661	509	650	481	650
Ditto all ground to pass No. 50 Sieve ..	572	—	542	675	505	710
Siftings only passed through No. 50 Sieve.	547	697	573	668	452	629

Table No. II. gives the results of further experiments made with the same object. It will be seen that in samples Nos. 1 and 2 the cement was actually improved by extracting the core that would not pass the No. 50 sieve; but sample No. 3, which was a very finely-ground cement, slightly deteriorated; and it will be further noticed that all three samples were improved by fine grinding. Though in this paper I am not going into the strength of mortars, it would be well to say that the fine grinding would give a more decided advantage in the case of mortars than in neat cement. Many people, even some manufacturers, consider the core to be the backbone of the cement, and to a certain extent they are in the right, but the result of these experiments proves that to be of value it must be ground. It is naturally the hardest burned particles which form the core, those which the mill stones have been unable to grind through their being of a harder nature than the rest of clinker. The core—therefore, as core, is really only so much sand in the cement—when ground acts in most instances beneficially and im proves the quality of the cement.

Table III.

No.	Specific Gravity.	Weight per striked Bushel.	Residue per cent.		Tensile Strength per square inch.		Increase per cent
			No. 25 Sieve.	No. 50 Sieve.	7 Days.	28 Days.	
1	3.09	116	2	16	509	650	27.7
2	3.00	116½	¼	13	400	550	37.5
3	3.00	116½	0	14	471	594	26.1
4	2.99	118	4	28	605	772	27.6
5	2.96	116	4	26	586	767	30.9
6	2.95	113½	3	33	473	558	17.9
7	2.90	111	7	30	701	718	2.4
8	2.90	118½	8	33	693	728	5.0

Table III. gives the results of experiments made with eight samples of cement, showing the specific gravity, weight per bushel, fineness, tensile strength at seven and twenty-eight days, and the increase per cent. between those dates. If we examine the specific gravity and weight per bushel in con junction with the fineness to which the cement is ground, it will be seen that a heavy weight per bushel and a heavy specific gravity denote a well-ground cement—while a heavy weight per bushel and a light specific gravity denote a badly-ground cement. It has been proposed to substitute the specific gravity for the weight per bushel when testing cement; but it must be remembered that the object of testing cement is not only to determine the actual strength of the cement at a given date, but to be able to form a fairly-accurate opinion as to its probable behavior in practice. I therefore think that to do away with the weight-per-bushel test, would be, to say the least, undesirable, as when taken in conjunction with the fineness, a very fair opinion can be formed of the value of a cement—an opinion which can be confirmed by afterwards taking the specific gravity; in fact the specific gravity, weight per bushel, and fineness, bear a certain relative proportion to each other, indicating either a light or heavily-burned cement. By again referring to Table III we find that the cements having a light specific gravity are quick-setting cements, which in seven days have already attained great strength, but which show but little improvement afterward, while those having a heavy specific gravity are slower in setting, and at seven days do not show such good results but continue to improve for a longer period. It is unfortunately impossible to lay down an absolute rule by which to determine the value of a cement, as almost every property, whether to its advantage or disadvantage, which it possesses, may be traced to more than one cause, and therefore might lead to opposite results in practice; and when it is remembered that an opinion, to be of any practical utility, must be given in a few days, and before the cement is required for use, it becomes entirely a matter of experience and thorough knowledge of the process of manufacture, to be able to give a reliable opinion as to the suitability of a cement to the work for which it is intended, by reference only to the problematical tests. Having considered what I have called the problematical tests of cement, viz., its weight, fineness, and specific gravity, and shown the results which may be expected by this preliminary examination, there remain to consider the absolute test of tensile strength, and the manner in which it is carried out. The object of the test for tensile strength is to obtain the best possible results under certain conditions. The conditions are generally those already given in the extract from the regulations of the Metropolitan Board of Works. It is evident that to obtain the best results much must depend on the manipulation of the cement, the manner in which it is gauged, the amount of water which is used for the purpose, the care with which it is placed into and removed from the moulds, the length of time which is allowed to elapse after gauging before it is placed in the water, the form of the mould used, and many other minutiæ of manipulation which can only be acquired by actual experience and practice. The amount of water which is required to reduce a cement to a proper consistency, or technically to properly gauge it, varies from 16 per cent. to 20 per cent. A quick-setting cement generally requires a larger per-centage of water than a slow-setting one, but the exact amount required can only be determined by actual experiments with the sample under examination. The amount of water required also depends upon the skill of the manipulator, as an experienced gauger will bring the mass to a proper consistency with less water than another of less experience or skill, and as the amount of water used materially affects the result obtained, the importance of using a minimum cannot be overestimated. Many of the discrepancies which arise when testing cement are undoubtedly due to this cause. With the object of over-coming this difficulty I have devised a small machine for gauging cement, and I find that by its use less water is required, and that the operation of gauging is done much quicker, both points which materially affect to its advantage the result obtained. The custom seems to have become general that the briquettes should be placed in water twenty-four hours after gauging; this time, though it is perhaps convenient to gauge up on one day and place the briquette in water on the next, gives a slow-setting cement every chance, still it certainly does not act beneficially on a fairly quick-setting cement, and it is generally advisable to place the briquette in water as soon as it is possible to remove it from the mould without fear of damage; the twenty-four hours may be taken as the limit of time, as, though a cement which has not by then set sufficiently to bear removal from the moulds may be a fairly good cement, it is too slow in setting to be of much practical value.

Again, with regard to the area of

Table IV.

No.	Tensile Strength Section 1 in. Square. 7 Days.	28 Days.	3 Months.	Increase or Decrease per cent. at 28 Days.	Increase or Decrease per cent. at 3 Months.
	lbs.	lbs.	lbs.		
1	380	210	..	−44.73	
2	701	718	728	+ 2.43	+ 3.85
3	510	647	716	+26.86	+40.39
4	605	772	826	+27.60	+36.52
5	476	662	..	+39.07	
6	693	728	..	+ 5.05	
7	589	764	901	+29.88	+52.97
8	666	810	..	+21.62	

breaking section of the briquette, it is usual to specify that the cement shall carry so much on the square inch, and yet the briquette generally in use has a breaking section of 1.5 in. square, giving an area of 2.25 in. How this custom has arisen I am unable to say, but it would undoubtedly greatly assist in clearing up many of the discrepancies now to be met with if one uniform section and form of briquette were adopted; and inasmuch as the strength on the square inch is specified, it would seem natural that the briquettes should have that area of breaking section. It will be readily understood that the form of the briquette has much to do with the result obtained, and it is essential that the strain put on the briquette should be tensile only, all crushing forces being detrimental and often resulting in the fracture occurring elsewhere than at the smallest part, and hence giving a false result. Also, that the briquette should be capable of easy removal from the moulds in which it is gauged—avoiding all necessity of knocking the mould in order to remove it—as such is liable to injure the set of the cement.

There is another matter which seems to be overlooked, or at all events not estimated at its full value, by experimenters with cement, viz., the increase in strength between a briquette broken at the expiration of seven days, and at the expiration of twenty-eight days. Many cements will stand the ordinary test at seven days, and yet be utterly worthless at twenty-eight days; others will give a good result at seven days and improve but little afterwards, while a cement that gives a comparatively low result at the expiration of several days may, at the expiration of twenty-eight, have considerably increased in value. The result of the subjoined experiments shows that this is a most important matter in estimating the ultimate strength of a cement.

By an examination of Table IV it will be seen that No. 1 was a cement that actually satisfied all requirements at the expiration of seven days, and yet at twenty-eight days was actually worthless, being much blown, and consequently having no strength whatever; and it would undoubtedly have pulled to pieces any work in which it was used. Nos. 2 and 6' were both strong quick-setting cements, and showed good results at the expiration of seven days, in fact they seem in that short time to have attained almost their ultimate strength, as their increase during the next three weeks was but 2 and 5 per cent. The other samples show results varying from 20 to 40 per cent. increase in tensile strength between the seven and twenty-eight days, and it will be seen that at longer dates the quick-setting cements are by no means the strongest. The importance of fine grinding is again exemplified by examples Nos. 6 and 8. No. 6 is the cement as received from the works—33 per cent. of it would not pass through the No. 50 sieve. No. 8 is the same cement, but ground so fine that it would all pass the same mesh sieve—while in the cement as delivered, the increase in strength between the seven and twenty-eight days was but 5 per cent., though when ground it amounted to 21 per cent. In this paper I have treated solely of what may be considered good cements, and have given the result of the tests made with them under different conditions. The failure of a cement by expansion or contraction during the process of setting has not been brought under consideration, but it is needless to say that a cement which does either would be a dangerous cement to use, the only exception being that a good cement will sometimes blow if used too soon after it has left the mill and before it has had time to cool; such a cement would, after being properly warehoused, be perfectly reliable. The deductions which I draw, and which I have endeavored to prove from the experiments, are:—1. That the weight per striked bushel, unless taken in conjunction with the fineness to which the cement is ground, is absolutely valueless as a guide to the quality of a cement, and that therefore the two should always be taken in combination, and that it is also advisable when possible to take the specific gravity. 2. That the finer a cement is ground the less it will weigh per striked bushel, but that it will at the same time be stronger. 3. That the core or coarse particles in a cement act deleteriously, and can be compared only to so much sand. 4. That to be able to form a true opinion of the value of cement, briquettes should, when practicable, be tested at twenty eight days as well as at seven, and that the greater the increase per cent. is between those dates the stronger and harder is the cement likely to become. The details of the weight and fineness, and other matters deduced from the foregoing tests, I have embodied somewhat in the form of a Specification, which I think meets most requirements, but the purposes for which a cement is to be used must of necessity govern many clauses. Thus:

SPECIFICATION.

Sample.—From each delivery of cement on to the works a sample of about one bushel will be taken indiscriminately from at least twelve sacks or casks, as the case may be, and will be subjected to the following tests, with the whole of which it will have to comply. The sample thus taken will be considered to indicate the quality of the entire delivery.

Fineness.—The cement to be so finely ground that it will all pass without leaving any residue when sifted through a copper wire sieve having 625 holes to the square inch, and when sifted through a similar sieve having 2,500 holes to the square inch, the residue, or that which is unable to pass through, shall not be more than 15 per cent. of the bulk before sifting.

Weight.—The weight per striked bushel to be not more that 116 pounds nor less than 108 pounds, but the weight must in all cases depend upon the fineness; thus, according to requirements, a cement which, when sifted through a sieve, having 2,500 holes to the square inch leaves a residue of from 12 to 15 per cent., must weigh not less than 112 pounds per striked bushel; should the residue be from 8 to 12 per cent. the minimum weight to be 110 pounds, and should there be less than 8 per cent. residue, the minimum weight to be 108 pounds per striked bushel. The bushel measure to be placed on a level floor where there is no vibration, and in every case filled from a zinc or other smooth-surfaced shoot, placed at an angle of 55 degrees, the lower end of the shoot to be 5 inches above the top edge of the measure. The cement to be allowed to run continuously along the shoot until the cement in the measure is well piled up, when it is to be struck level with a straight edge. In no case is the measure to be in any way touched or shaken, until it has been struck.

Specific Gravity.—The specific gravity to be not less than 2.95 nor more than 3.1.

Tensile Strength.—Twenty briquettes to be gauged from each sample, ten to be broken at the expiration of seven days from the date of gauging, and ten at the expiration of twenty-eight days from the date of gauging. Those broken at seven days to carry an average weight of 400 pounds per square inch of section without fracture, and those broken at twenty-eight days to show an increase in strength of 25 per cent. over those broken at seven days.

The following particulars are to be observed in gauging the cement to form the briquettes: The contractor to use any form or section of mould he chooses in which to make the briquettes, provided always that the breaking sectional area of the briquettes be not less than one square inch. The moulds in which the briquettes are made to be placed on glass or other non-porous beds. The amount of water used for gauging the cement not to be more than 19 per cent. of the whole. The briquettes to be removed from the moulds and placed in water within twelve hours from the time of gauging and allowed to remain therein until they are due for breaking (which will in every case be reckoned from the time of gauging and not of placing in water), and to be broken immediately on being taken out of the water.

Expansion or Contraction.— Pats about 3 or 4 inches square and about $\frac{3}{4}$ inch in thickness (gauged with the same per centage of water as is used in forming the briquettes), placed on pieces of glass, to be immersed in water within four hours after gauging, and to show neither cracks on the edges nor on the surface, nor deviation in form when examined at the expiration of seven days.

THE SLIPPING OF LOCOMOTIVES.

From "Engineering."

Some two years or so ago prominent attention was directed to this matter by M. Rabeuf, who carried out on the Northern Railway of France some experiments which certainly yielded startling results. These experiments were made with a four-coupled engine having coupled wheels 7 ft. in diameter, and carrying a total load of 27 tons. In fine weather M. Rabeuf found that this engine, when running light at the high speed of $74\frac{1}{2}$ miles per hour down a gradient of 1 in 200, apparently slipped continuously to the extent of 19 per cent., while other engines also gave results of a very similar kind, the slipping at maximum speeds apparently varying from 13 to as much as 25 per cent. According to M. Rabeuf's observations, the percentage of slipping increased with the speed, and was greater on descending than ascending gradients.

These results obtained by M. Rabeuf naturally received considerable attention, and they have been analyzed in France by MM. Desmousseaux de Givre and J. Morandière, and in Italy by Signor Oppizzi. We have not space here to enter into the details of the investigations made by these engineers, but we may say that the general explanation arrived at is to the effect that at very high speeds not only is the coefficient of adhesion modified, but during certain portions of the revolution of the driving-wheels the pressure of the wheels on the rails is materially affected by the action of the unbalanced rotating parts, &c. When working at a high grade of expansion, as would probably be the case with a light engine descending an incline, the effective moment of rotation due to the action of the steam in the cylinders, of course, varies considerably at different parts of a revolution, and the coincidence of a maximum moment of rotation with the diminution of adhesion pressure above referred to, might, of course, result in slipping for a certain portion of each revolution of the driving-wheels. Signor Oppizzi, however, came to the conclusion that this action is not likely to occur at the ordinary speed at which trains are worked, and that M. Rabeuf's results were thus of an exceptional character.

While, however, M. Rabeuf's experiments have been thus discussed, there seems to have been no effort to check the accuracy of his deductions until the matter was again taken up on the Northern Railway of France last year by M. J. de Laboriette, who has lately contributed to the *Revue Générale des Chemins de Fer* a very interesting memoir on the subject, describing his mode of experimenting and the results which he has obtained. The apparatus employed by M. J. de Laboriette in his researches was arranged to obtain electrically, by the use of a Morse printer, a record of every revolution made by the driving-wheels. According to the arrangement first employed, one pole of a battery was placed in communication with the driving-axle of the engine on which the experiments were being made, while the other pole was connected to a long metallic brush, insulated and mounted on the driving horn-plate of the outside frame of the engine, so that at each revolution the brush came into contact with the outside crank on the driving-axle. The circuit was thus completed once during each revolution, and a Morse printer being placed in the circuit a mark was made on a traveling band of paper for every revolution made by the driving-axle. It was found, however, on trial that this arrangement was not entirely satisfactory, the contact between the metallic brush and the crank arm being very brief, and not always sufficiently perfect to secure the completion of the circuit, and there was, therefore, substituted for the brush arrangement an "interrupter" worked from a reciprocating part of the engine, and arranged so as to complete the circuit once during every revolution. This "interrupter" consisted simply of a vibrating lever connected to one pole of the battery, and carrying a spring which during a portion of the oscillation of the arm rested upon an insulated surface, and during the remainder of the oscillation completed the circuit by bearing upon a metallic arc in electric communication with the other pole of the battery. The revolutions of the driving wheels being recorded in the manner just described, there remained to be recorded the distance run by the engine, and this was done by an observer, who marked on the traveling band of paper the passage of the engine past each kilometer post, the instant of passing being announced by a second observer striking a bell. Slight errors, due to the observers, or to the want of absolute accuracy in the spacing of the kilometer posts, were eliminated, by making each experiment continuous over a number of kilometers, while the apparatus was fitted to a dynamometer van, so that observations of the tractive force exerted by the engine could be simultaneously made.

The experiments carried out by M. J. de Laboriette were carried out on six locomotives of three different types, five of the engines having each four coupled wheels, while the sixth was a Crampton engine with a single pair of driving wheels. In each case the circumference of the wheels was obtained with great care, not by measuring the diameter, but by moving the engines slowly on the rails and measuring the distance traversed for a complete revolution. The trains hauled during the experiment varied in length from 12 to 22 carriages, and the speeds from 70 to 90 kilometers (43½ to 56 mlles) per hour, while the results show that under the conditions existing on these trials no slipping whatever occurred. In fact, the agreement between the actual distances run and the distances as measured by the revolutions of the driving wheels, as recorded by the tables in the manner above referred to, is extraordinarily close, and speaks most highly for the accuracy with which the measurements were made, the difference never exceeding a small fraction of a revolution per kilometer.

M. J. de Laboriette's experiments may be considered to entirely set at rest any doubt which may have arisen as to the partial slipping of driving wheels under the ordinary conditions of locomotive working, proving as they do that no such continuous slipping exists, and that hence this supposed action has not to be taken into consideration as a cause of wear and tear. We trust that on some future occasion M. J. de Laboriette may be able to extend his researches (if he has not already done so) to the investigation of the action which takes place at the exceptionally high speeds attained by M. Rabeuf in his experiments, so that the results obtained during these trials may be checked by independent observations. Speeds of over 60 miles per hour are now common with many of the express trains in this country, and it is daily becoming of more importance that the working of locomotives and the resistances of trains at these high speeds should be thoroughly investigated. Theory has shown that at exceptionally high speeds partial slipping may be produced from the causes to which we have already alluded, and it appears to us well worth while to check the deductions of theory by experiment, and to ascertain whether with locomotives, as now proportioned, there exists an obstacle to the attainment of very high speeds which has hitherto not been generally appreciated. So far the investigation of this matter has been left to Continental engineers, but there is every reason why, with the fast traffic to be dealt with here, it should be made the subject of careful experiment in this country, and we hope, therefore, to hear of its being taken up thoroughly by some of our locomotive superintendents.

GASES, LIQUIDS, AND SOLIDS.

From the "English Mechanic and World of Science."

The series of experiments recently made by Mr. J. B. Hannay and Mr. J. Hogarth, the most remarkable outcome of which is the production of crystallized carbon, carry the work of Pictet and Cailletet another step forwards in a slightly different direction. Those able investigators demonstrated that gases could be converted into solids, and Messrs. Hannay & Hogarth have now shown that there is a perfect continuity between the gaseous and the liquid states, and have supplemented the labors of Dr. Andrews by some elaborate and valuable researches which have been so far rewarded by the crowning discovery of artificial diamonds. The experiments were primarily commenced with the view of throwing further light on what Dr. Andrews called the "critical state" of matter. Carbonic acid at 35.5° C., and under a pressure of 108 atmospheres is, according to Dr. Andrews, midway between a gas and a liquid, and the chemist would be puzzled to assign reasons for classing it under one head in preference to another. If the property of dissolving solids is peculiar to liquids, there would necessarily be some deposit of solid from a solution when the latter was passing the critical point, but if not the fact would be a further proof of the continuity of the liquid and gaseous states. At first Messrs. Hannay & Hogarth adopted a modification of Dr. Andrews' apparatus, and as this will have an interest for many of our readers we briefly describe it. Wrought iron hydraulic tubing about $\frac{1}{2}$ inch internal and 1 inch external diameter was used as the earliest pressure appliance. The length was 9 inches, and a side tube for the insertion of the manometer was welded on. The ends were closed by strong screw-caps, through one of which the experimental tubes were passed, while the other was used as a kind of gland, through which the pressure-screw ($\frac{1}{4}$ inch diameter, 30 threads to the inch) was admitted to the tube. The packing consisted of a solid plug of rubber, about $\frac{1}{2}$ inch thick, placed in the caps; in the case of the screw, the hole through the rubber was lined with thin leather, well soaked in lard, while, to prevent the experimental tubes being forced out through the hole in the cap, a spreading of the gas was produced, which bore against a strong leather washer. In cases where very high pressures were required, the tubes were cemented in with oxychloride of zinc. This method of packing will be a hint of some use to experimentalists, for although pressures up to 880 atmospheres were sometimes reached, the apparatus was free from leakage, and was as tight with mercury as with water. When high temperatures were also required, the experimental tube, after leaving the pressure-cylinder was bent down and up and passed into an air-bath of two concentric iron cylinders, with mica windows for observing the effects. The method of carrying out the experiments was much in the following way: A glass tube was fixed in the apparatus previously filled with mercury, and a small quantity of alcohol was drawn in by reducing the pressure. A fragment of fused potassic iodide was then dropped in and heat was applied to boil the alcohol and expel the air, when the tube was sealed by the blowpipe. Precautions were taken to prevent the liquid alcohol from touching the potassic iodide while the tube and its contents were raised to a temperature of 300° C. Pressure was then increased until the alcohol was reduced to about the volume occupied in its fluid state, when the fragment of potassic iodide was seen to dissolve gradually and completely, although the alcohol was in the condition of a gas, using that term in Dr. Andrews' sense of a fluid at any temperature above its critical point, which, in the case of alcohol, according to Messrs. Hannay & Hogarth, is 234.4° C. On slowly withdrawing the screw no deposit occurred, but when the screw was turned out rapidly a crystalline film appeared on the glass, and in some cases a cloud of fine crystals in the menstruum, both of which could be easily redissolved by increasing the pressure. The existence of the solvent power above the critical point being thus established, experiments were made with other solvents and solids. Some interesting information was gained by these investigations, and some more or less valuable discoveries may be expected to spring from them. A solution of sulphur in bisulphide of carbon, for instance, showed no sign of separation when raised 50 centigrade degrees above the critical point. Selenium also remained in solution in the same menstruum when heated above the critical point, but a chemical action took place, sulphide of selenium being probably formed. The apparent solubility of arsenic was also probably due to the formation of a sulphide. With many other substances, chemical changes appeared to occur without signs of solution. An interesting experiment to determine whether the absorption spectrum of a substance dissolved in a fluid above the critical point would be the same as in liquid solution, or when acted upon in the solid state, was answered in the affirmative, for a solution of anhydrous cobaltous chloride sealed in a tube, and heated beyond the critical point showed no difference beyond a fainter and more nebulous character of the bands, caused by expansion: their position was not changed. At the suggestion of Prof. Stokes, a similar experiment was tried with chlorophyll, with a similar result. Many other experiments were made, but we must refer those interested to the full description which will be issued in the *Proceedings* of the Royal Society. The investigations, so far as they have gone, are but the starting-point for others, and we may fairly expect a great development of this branch of research within the present year. The most interesting outcome of the present experiments is the discovery of the artificial production of the diamond, a supplementary paper on which, by Mr. Hannay, was read at a recent meeting of the society. While pursuing the investigation we have referred to briefly above, Mr. Hannay noticed that many bodies, such as silica, alumina, and oxide of zinc, insoluble in water at ordinary temperatures, dissolve to a large extent when treated with water-gas at high pressures. It occurred to him that a solvent might possibly be found for carbon, and as the gaseous solutions nearly always yielded crystalline solids on withdrawing the solvent or lowering its solvent power, it did not seem improbable that carbon might be obtained in the crystalline or diamond state. A number of experiments were accordingly made with charcoal, lampblack, graphite, but instead of solution, only a chemical action was induced. A curious reaction was, however, noticed, which seemed likely to tend to further discovery by furnishing carbon in the nascent state, and consequently easily soluble. When a gas containing hydrogen and carbon is heated under pressure in presence of certain metals, its hydrogen is attracted by the metal, and its carbon left free. That discovery, which is a very important one, is probably explained, as suggested by Prof. Stokes, by the discovery of Profs. Liveing and Dewar, that at high temperatures hydrogen has a strong affinity for certain metals, notably magnesium, with which it forms remarkably stable compounds. Now Mr. Hannay found that when the carbon is set free by this action of the hydrogen in the presence of a stable compound containing nitrogen, the whole being nearly at red heat and under enormous pressure, the carbon is so acted upon that it can be obtained in the clear transparent form of the diamond. The "stable compound containing nitrogen" is, however, for the present his secret. The greatest difficulty he has found is the construction of an apparatus strong enough to resist the enormous pressure, combined with a high temperature, for while the 1 inch hydraulic tubing sufficed for the earlier experiments, and withstood pressure ranging up to 880 atmospheres, tubes constructed on the gun-barrel principle, having a bore of half an inch, and an external diameter of four inches, were torn open in nine cases out of ten by the pressure found necessary to crystallize carbon. Mr. Hannay, we understand is in treaty with the makers of steel tubes for some specially strong specimens, and it is evident that we have not heard the last of his experiments, though the cost of the diamonds he has at present produced is necessarily far higher than the prices asked for similar crystals of nature's production. According to Mr.

Hannay, the carbon he obtained is as hard as natural diamond, a statement corroborated by the evidence of Mr. Maskelyne, and is also in crystals with curved faces belonging to the octahedral form. These burn readily on thin platinum foil over a blowpipe, and when ignited by an electric current in oxygen show a composition of 97.85 per cent. of carbon. Immersed in hydrofluoric acid for two days, no sign of solution is exhibited even when boiled. The crystals answer other tests, but as yet no perfect crystals have been submitted to experts, only crystalline fragments; and as the position of science is ever one of scepticism until the truth is demonstrated, the authoritative acknowledgment of Mr. Hannay's discovery will not be made until further experiments have enabled him to prove transmutation of carbon beyond the shadow of a doubt. The apparatus and all analyses are to be fully described in a paper to the Royal Society, but there is little question that Mr. Hannay is the first to show specimens of crystallized carbon produced in the laboratory of the chemist. We incline to the opinion, however, that his researches into the solubility of solids in gases will ultimately be found of more scientific value than his discovery of artificial diamonds.

EUPHRATES VALLEY ROUTE TO INDIA.

By W. P. ANDREW.

From "Journal of the Society of Arts."

Seldom has the public mind—I may say that of Europe—been so completely engrossed as at this moment by the Central Asian question, owing rather to the magnitude and uncertainty of events, to which it may at a future time give rise, than to its more immediate and palpable consequences.

Here, in England, it is not surprising that the recent movements of Russia—taken in conjunction with the position in Afghanistan of our heroic countrymen and their gallant brothers in arms, whether Mohammedan or Hindoo—should excite men's minds, and should make us more determined than ever for the maintenance of our *prestige* in Europe and the safety of our Empire in the East. But while, in our desire to avoid political complications, we have devoted ourselves, with much assiduity, to the discussion of minor geographical questions, we have overlooked the simplest and most obvious means of checkmating the possible designs of Russia, by closing the gates of India, the Bolan and the Khyber, and by a parallel movement along the Valley of the Euphrates. It is right, therefore, at the present juncture, once more to invite attention to the proposed establishment of a direct and rapid route to our Eastern possessions, by the ancient highway of the Euphrates.

In the proposal to restore this ancient route—once the highway of the world's commerce, and the track of the heroes of early history—by the construction of a railway to connect the Mediterranean and the Persian Gulf, we have at hand an invaluable and perfectly efficient means at once of thwarting the designs of Russia, if they should assume a hostile character; of marching hand-in-hand with her, if her mission be to carry civilization to distant lands; and of competing with her in the peaceful rivalry of commerce.

Of all the lessons which recent wars have taught us, none is more emphatic than this, that henceforth the power of nations must be upheld by the knowledge and use of mechanical appliances. Among the most important of these are railways, as we saw in the Franco German war. A vague presentiment of this marvelous revolution had long existed, but it had to struggle against apathy and deep-seated prejudice. The true secret of national supremacy has, however, now been brought home with irresistible force to the most reluctant mind; and it behooves us to brace ourselves anew for a more determined progress, if we would retain the prestige and influence we have hitherto enjoyed as a great nation.

In the Crimean war we saw, with certainty, where the power of the Czar first gave way. The telegraph and rail were the missing links in his armor. He had built fortresses of colossal magnitude, collected resources astonishing from their variety and abundance; his generals were selected with consummate skill, while over the persons and property of his subjects he exercised unlimited control. But, had the Czar been able to whisper his commands with lightning speed, and been obeyed with promptitude, how different might have been the result! The giant aggressor was, by a handful of invaders, with telegraph and steam in connection with the bases of their operations, defeated and humiliated on the soil of holy Russia herself.

We all now know how alive Russia has now become to the necessity of following up her advances by improved means of communication. It is inconceivable that any power but England, having either means or credit at command, would hesitate how to act under such circumstances as those in which we are placed. To us it has been a continual reproach that we are never ready for the emergencies which we might readily have foreseen. Let us not refuse, therefore, to learn wisdom by the experience of the past, or some day we shall assuredly be called on to spend untold treasure to retrieve disasters which a little timely forethought would have enabled us to avert.

Few facts bear more conclusive testimony to the sagacity of the ancients, when the limited amount of their geographical knowledge is remembered, than the tenacity with which commerce adhered to the direction given to it by them, and the readiness with which it returns to any of those channels when temporarily diverted by political events, or geographical discoveries. The overland route from Europe to India, by the Isthmus of Suez and the Red Sea, is certainly as old as the days of the early Phœnician navigators. The navigability of the Euphrates was tested long before Trajan ever sailed on its waters, and was re-visited by the Italians in the eleventh century, and our own merchants in the days of Elizabeth, as the best way to the East; whilst the value of the Indus, as the shortest and easiest route for the commerce of India, not only with Central Asia and the North of Europe, but with the whole of the West, was fully recognized by the later Romans in the seventh century. When the rapid progress of the Mohammedan arms had wrested Egypt from the Byzantine power, and thus closed the overland route of Suez to the Greek merchants, they forthwith turned to other means, and sought out a new channel by which the productions of the East might be transmitted to the great Emporium of the West. The route thus discovered was that by the Indus. The rich and easily stowed products of India were carried up by this great river as far as it was navigable, thence transported to the Oxus, down whose stream they proceeded as far as the Caspian Sea. There they entered the Volga, and sailing up it, were carried by land to the Tanais (the Don), which conducted them into the Euxine Sea, where ships from Constantinople waited their arrival.

Various causes concurred in restoring liberty and independence to the cities of Italy. The acquisition of these roused industry, and gave motion and vigor to all the active powers of the human mind. Foreign commerce revived, navigation was attended to and improved. Constantinople became the chief mart to which the Italians resorted. There they not only met with favorable reception, but obtained such mercantile privileges as enabled them to carry on trade with great advantages. They were supplied both with the precious commodities of the East, and with many curious manufactures, the product of ancient arts and ingenuity still subsisting among the Greeks. As the labor and expense of conveying the productions of India to Constantinople, by that long and indirect course which I have described (the route by the Indus, the Oxus, the Caspian, and the Volga), rendered them extremely rare, and of an exorbitant price, the industry of the Italians discovered other methods of procuring them in greater abundance, and at an easier rate. They sometimes purchased them at Aleppo, Tripoli, and other ports on the coast of Syria, to which they were brought by a route not unknown to the ancients. They were conveyed from India by sea, up the Persian Gulf, and, ascending the Euphrates and Tigris, as far as Bagdad, were carried by land across the desert of Palmyra, and from thence to the towns on the Mediterranean.

The discovery of the long but easy route by the Cape of Good Hope, combined with the deadly feuds between the Christians of the West and the Mohammedan nations that held the countries of the Nile and the Euphrates, for a time diverted the stream of commerce from those routes. It has not been so, however, with the Indus to the same extent. If the revival of the Overland Route, and the impending re-opening of the Euphrates as the highway to the East, are evidences of a return to old paths, the continuance of a commerce with Central Asia and Northern Europe by way of the Indus, and the two great gates of India, the Khyber and Bolan Passes, is a pregnant proof of the tenacity with which trade adheres to its old channels, and of the sagacity which originally selected that direction for the produce of the East. However great may have been the changes of masters and manners in the territories between the Indus and the Bosphorus, a portion of the tide of commerce has flowed, and does still flow, as it did in the seventh century.

When the late Sir Alexander Burnes was in Lahore, in 1831, he found English broadcloth sold in the bazaar that had been brought, not from Calcutta, but from Russia; and, when he penetrated further into Central Asia, met, at Bokhara, with a merchant "thinking of taking an investment of it to Loodhiana, in India, where he could afford to sell it cheaper than it was to be had there, notwithstanding the length of the journey."

The countries which our future highway to India will traverse have been, from remote antiquity, the most interesting in the world. On the once fertile plains, watered by the Euphrates and Tigris, the greatest and most glorious nations of antiquity arose, flourished, and were overthrown. The earliest home of the genius of civilization—the scene of great events in the early history of the world, now shrouded in the dust of ages, or dimly discerned through the long vista of many centuries—the land of the Assyrians, Babylonians, and Chaldeans; where the daughters of Zion sat and wept; where lay the track of Xenophon and his heroic 10,000 Greeks—the center of the conquests of the Macedonians; where once stood the proud capitals of the Sassanides and of the Caliphs, now deserted and tenantless—these regions must ever possess a fascination and interest for all mankind.

The first city of the new earth was built upon the banks of the "Great River." The tower of pride, erected by the post-diluvian population, cast a shadow over its waters. The Euphrates intersected Babylon, the "Golden City," the "Glory of Kingdoms," the great capital of the Chaldean Empire—now a desolation among the nations, her broad walls utterly broken, her high gates burnt with fire. With Babylon are associated the names of Nebuchadnezzar and Belshazzar, of Daniel and Darius, of Cyrus and Alexander. The grand prophet of the captivity, and the energetic apostle of the new era, had their dwelling within her walls. Ere even a brick was made upon the Nile, Nineveh and Babylon must have had thriving and busy populations.

Twice in the world's history mankind commenced the race of civilization on the Mesopotamian rivers. Twice the human family diverged from their banks to the east, the west, and the north. Arts and sciences made the first feeble steps of their infancy upon the shores of these rivers. Very early in history we know that Babylon was a great manufacturing city, famed for the costly fabrics of its looms. At a more recent date, the Chaldean kings made it a gorgeous metropolis; Alexander of Macedon made it the port of the Indian Ocean and the Persian Gulf, and he proposed to render it the central seat of his imperial power.

The countries through which the Euphrates flows were formerly the most productive in the world. Throughout these regions, the fruits of of temperate and tropical climes grew, in bygone days, in profusion. Luxury and abundance were universally diffused. The soil everywhere teemed with vegetation. Much of this has since passed away. Ages of despotism and misrule have rendered unavailing the bounty of nature. But the land is full of hidden riches. The natural elements of its ancient grandeur still exist in the inexhaustible fertility of the soil, and in the chivalrous character and bearing of many of the tribes; and the day cannot be far distant when it is destined to resume its place amongst the fairest and most prosperous regions of the globe.

The wondrous fertility of Mesopotamia was, in early times, carried to its utmost limit by means of numerous irrigation canals, with which the country was everywhere intersected, and some of the largest of which were navigable. These excited the wonder and interest of Alexander the Great, who, after his return from the conquest of India, examined them personally, steering the boat with his own hand. He employed a great number of men to repair and cleanse these canals.

Herodotus, speaking of Babylonia, says:—

"Of all the countries I know, it is, without question, the best and the most fertile. It produces neither figs, nor vines, nor olives; but, in recompense, the earth is suitable for all sorts of grain, of which it yields always 200 per cent., and, in years of extraordinary fertility, as much as 300 per cent."

These regions need only again to be irrigated by the life-giving waters pouring down, ever cool and plentiful, from Arrarat—that great land-mark of primeval history, now the vast natural boundary-stone of the Russian, Turkish, and Persian empires—to yield once more in abundance almost every-thing that is necessary or agreeable to man. Many acres, now wasted, might be covered with cotton, tending to the employment of the millions of spindles of our land.

It is not too much to say that no existing or projected railroad can compare in point of interest and importance with that of the Euphrates Valley. It will bring two quarters of the globe into juxta-position, and three continents—Europe, Asia, and Australia—into closer relation. It will bind the vast population of Hindostan by an iron link with the people of Europe. It will inevitably entail the colonization and civilization of the great valleys of the Euphrates and Tigris, the resuscitation, in a modern shape, of Babylon and Nineveh, and the re awakening of Ctesiphon and Bagdad as of old.

It is by distance and difficulties of intercourse that the distinctions of creeds and races are chiefly upheld. Annihilate space, and the great barriers that separate people—the differences of manners and customs, of modes of thought and feeling, of doctrines and dogmas, of precepts and prejudices, that keep up these barriers—gradually disappear, as barbarism, superstition and ignorance give way to the superior and irresistible force of civilization, truth and enlightenment.

Although various routes have been suggested with the view of bringing Great Britain, by means of railway communication, into closer connection with India and her other dependencies in the East, and of securing, at the same time, the immense political and strategic desideratum of an alternative highway to our Eastern possessions, there is none which combines in itself so many advantages as the ancient route of the Euphrates—the route of the Emperors Trajan and Julian, in whose steps, in more recent times, the Great Napoleon intended to follow, when the Russian campaign turned his energies in another direction.

The special advantages which render this route superior to all others are briefly these:—It is the most direct route to India. It is the shortest and the cheapest, both for constructing and working a railway, so free from engineering difficulties, that it almost appears as though designed by the hand of Nature to be the highway of nations between the East and the West; the most easily defensible by England — both of its termini being on the open sea; and the most likely to prove remunerative.

Both from an engineering and a political point of view, the Euphrates route undoubtedly possesses great advantages over any of the others which have been proposed. All the routes which have been suggested from places on the Black Sea are open to the fatal objection that, while they would be of the greatest service to Russia, they would be altogether beyond the control of Great Britain, while the engineering difficulties with which they are surrounded are, of themselves, sufficient to exclude them from practical consideration.

This has been fully established by the evidence of the witnesses examined by the Select Committee of the House of Commons, which, in 1872, investigated the merits of the various proposals for connecting the Mediterranean and the Black Sea with the Persian Gulf.

In the course of the investigation by the Committee, it was conclusively demonstrated that the proposed Euphrates Valley Railway is an eminently feasible undertaking in an engineering sense; that the route of the Euphrates and the Persian Gulf is decidedly preferable, in respect of climate, to that of Egypt and the Red Sea; that, as regards the safety and facility of the navigation, the Persian Gulf also has by far the advantage; that the proposed undertaking would be of great commercial moment, and, if not immediately profitable, at all events, that it would be so at a date not far distant; and, finally, that it would be of the highest political and strategic importance to this country.

It is unnecessary to quote in detail from the evidence taken by the Committee, but, in order to show how authoritative were the conclusions in favor of the undertaking aimed at by the Committee, I may state that the engineering facilities which exist for the construction of a railway from the Mediterranean to the Persian Gulf were demonstrated by the evidence of the late General Chesney, the veteran explorer of the route; by Captain, now Admiral, Charlewood, of the Royal Navy, and Mr. W. F. Ainsworth, two of the officers attached to the Euphrates Expedition; by Sir John Macneill, Mr. Telford Macneill, Mr. W. J. Maxwell, Sir Henry Rawlinson, Captain R. F. Burton, and Captain Felix Jones. The advantages of the route, in respect of the climate and productiveness of the country to be traversed, were shown by the evidence of General Chesney, Mr. Eastwick, M. P., Captain Felix Jones, General Sir Henry Green, Colonel Malcolm Green, Mr. Consul Barker and others. Mr. Barker, who had resided twenty-six years as Vice-Consul and Acting Consul at Seleucia, Antioch, and Aleppo, and has, perhaps, as intimate an acquaintance with the country as any man living, stated in an official report, addressed by him to Lord Granville, that—

"A railway through Mesopotamia, as a route to India, would not, at first, be productive of much to a company from traffic, but in a few years—certainly before the railway could be finished—the cultivation of grain would increase a hundredfold, and would go on increasing a thousandfold, and would attain to a magnitude and extension quite impossible to calculate, because bad harvests are almost unknown in these parts, for there is always plenty of rain and a hot sun to ripen the corn. Populous villages would spring up all along the line, as there is abundance of sweet water everywhere. Cereals can be grown there so cheaply that no country the same distance from England—say, for instance, Russia—could compete with it at all. And, if Great Britain finds it necessary to rely more on the importation of foreign corn, where could a better field be found than the fertile plains of Mesopotamia, the cradle of mankind, which has all the advantages of climate, soil, sun and water in its favor."

The facility of the navigation of the Persian Gulf was testified to by Mr. William Parkes, Consulting Engineer to the Secretary of State for India for Kurrachee and Madras harbors, and also in a correspondence published by Captain A. D. Taylor, late of the Indian Navy. Mr. Edwyn Dawes gave some useful information of the great extension of commerce at all the ports of the Persian Gulf.

The advantages of the proposed undertaking from a military point of view were placed beyond question by the evidence of General Chesney, of Captain Tyler, R. E., and of those experienced soldiers, Sir Henry Green and Colonel Malcolm Green, and more especially by the weighty testimony of Field Marshal Lord Strathnairn; while its importance in a political sense was established by many witnesses, amongst whom I may instance Sir Bartle Frere, the late lamented Sir Donald McLeod, Mr. Palgrave, Colonel Herbert, her Majesty's Consul-General at Bagdad, Mr. Eldridge, Consul-General at Beyrout, and, pre-eminently, the "Great Elchi," the venerated Lord Stratford de Redcliffe.

Other nations, whose interests in the East are incomparatively less than ours, either on political or commercial grounds, have, in recent years, made great advances in extending their communications in an easterly direction.

The establishment of steam communication by the Messageries Maritimes on the Route of the Red Sea, to Calcutta and other Eastern ports, shows the importance attached by the French to the extension of their commercial relations with the East. A Russian line of steamers has been established, to run between Odessa and Bombay by the route of the Suez Canal, and the Italians and Australians are actively competing for a share in the Eastern trade. Even those who see no danger in the policy of annexation pursued by Russia, will admit that the Russian roads and railways now being pushed towards Persia and Afghanistan, if designed with pacific intentions, prove, at all events, the anxiety of the Russian Government to compete with us for the trade of Central Asia, the Punjaub, and Northern India. But the carriages and trucks ostensibly designed for peaceful and commercial purposes are so constructed as to be equally available for the conveyance of troops with munitions of war.

It behooves us, therefore, to be careful that we do not stand still in the career of improvement, and be left behind in the race by other nations, however friendly. Political disturbance in Europe might at any moment deprive us of our communications with India *via* Egypt. The canal, glorious work as it is, might be suddenly rendered useless. So long as the Indian Empire subsists, the connection between India and this country must be kept up. If that connection were interrupted for many months, the integrity of our Eastern Empire might be seriously menaced. England maintains her position in India mainly by force of arms; and it is a principle, both of war and of common sense, to take the most efficient means at our command to keep open the lines of communication between the base and the field of operations. Hence the necessity of establishing an alternative route, even if it were not a better one. But that by the Euphrates, the most ancient of all, is at once the shortest, the easiest, and the safest, and it can never be superseded by any other offering superior advantages.

Apart from the general question of the advantage, on strategic grounds, of possessing an alternative and accelerated route to our Eastern dominions, it is a matter of the greatest importance that, in case of an emergency we should be able to send troops to India at any season of the year. Viewed in this light, the Euphrates route presents a striking contrast to that *via* Egypt, which, during a portion of the year, could not be used for the transport of troops without a serious sacrifice of life, in consequence of the excessive heat of the Red Sea. The Euphrates route, on the other hand, would be available for this purpose at all seasons.

The substitution of Kurrachee for Bombay as the European port of India would, even by the Red Sea route, give us an advantage of some 500 miles; but, if the Euphrates route were once established, the adoption of Kurrachee as the European port of India would necessarily follow, and India would thus be brought upwards of 1,000 miles nearer to us than at present; while, during the monsoon months, the gain would be still greater, as the route between the Persian Gulf and Kurrachee is not exposed to the severity of the monsoon, which, it is well known, renders a divergence of some 500 miles necessary during a portion of the year on the voyage from Bombay to Aden. Kurrachee is now in railway connection with Lahore and Calcutta, and, when the railway system of the Valley of the Indus is completed as far as the Bolan and Khyber Passes, and extended to Candahar, the safety of India would be insured.

May I be permitted to repeat the words which I ventured to urge upon Lord Palmerston upwards of twenty years ago, when I accompanied, in support of the Euphrates Valley Railway, one of the largest and most influential deputations that ever waited upon a minister:—

"The grand object desired is to connect England with the north-west frontier of India by steam transit through the Euphrates and Indus Valleys. The latter will render movable to either the Khyber or the Bolan, the two gates of India, the flower of the British Army cantoned in the Punjaub; and the Euphrates and Indus lines being connected by means of steamers, we should be enabled to threaten the flank and rear of any force advancing through Persia towards India. So that by this great scheme the invasion of India would be placed beyond even speculation, and it is evident that the great army of India of 300,000 men being thus united to the army of England, the mutual support they would render each other would quadruple the power and ascendancy of this country, and promote powerfully the progress, the freedom, and the peace of the world."

The Euphrates and Indus lines together would, moreover, secure for us almost the control of the trade with Central Asia, enabling us to meet Russia, our great competitor in these distant fields of commercial enterprise, on more than equal terms.

But it is not on commercial considerations that I would urge the claims of the Euphrates Valley Railway. It is on imperial grounds that the scheme commends itself to our consideration. I believe that the establishment of the Euphrates route would add incalculably to our prestige throughout Europe and the East, and would do more to strengthen our hold on India than any other means that could be devised.

Although fully alive to the vast importance of the results which would accrue, not only to England and India, but to the cause of civilization generally, from the establishment of continuous railway communication between Europe and India, I cannot conceal from myself that such a project is too vast to be at once undertaken with any hope of success. But the Euphrates Valley Railway, as proposed, from the gulf of Scanderoon to the Persian Gulf, has been specially designed with a view to its ultimately forming part of a through line from Constantinople to the head of the Persian Gulf, while it is capable, also, of being, in due time, extended eastward to Kurrachee, the port of India nearest to Europe. The line from the Mediterranean to the Persian Gulf has been demonstrated to be eminently practicable and easy, which the other portions of the route between Constantinople and India are not. While capable of forming part of a through line, it would, at the same time, be complete in itself, and independent of any disturbances in Europe—the only portion, in fact, of a through line of railway which would be always, and under all circumstances, at the absolute control of this country. It would always be to this country the most important portion of any through line; and, indeed, I believe a through line could not be constructed, except at overwhelming cost, without the assistance of a port in northern Syria. It would, moreover, provide us with a complete alternative route to India, and would thus at once secure to this country advantages admitted to be of the highest national moment. It is for these reasons that, during the long period in which I have devoted myself to the advocacy of the Euphrates route to India, I have thought it expedient to urge upon our own government, and that of Turkey the special claims of that section only which would connect the Mediterranean with the Persian Gulf.

The objection that, although the Euphrates Valley Railway would afford us the undoubted advantage of an alternative, a shorter, and a more rapid means of communication with India, it would still leave a considerable portion of the journey to be accomplished by sea, and that consequently, it would accelerate our communications with the East in a minor degree only, is sufficiently disposed of by the circumstances already pointed out—that a railway from a point on the Mediterranean, at or near Scanderoon, to the head of the Persian Gulf, would naturally form part of a through line of railway from Constantinople to India, if, at a future time, it should be considered necessary or desirable to construct the remaining sections.

At the same time, it is to be observed that any possible acceleration of the journey between Europe and India, by the substitution of railway for sea transit, would be, relatively, much less in the case of those portions of the route traversing Asia Minor on the one hand, and Persia and Beloochistan on the other, than on the central section between Scanderoon and the Persian Gulf; the latter section being almost level for nearly the whole distance, and, therefore, capable of being traversed at a very high rate of speed; whereas, both in Asia Minor and Persia, the gradients would be so severe as to neutralize, in a great measure, the advantages ordinarily attaching to railway traveling as compared with that by sea. *Pro rata* to the power required, so is the distance. In other words, the proposed Euphrates Valley Railway would take advantage of precisely that portion of the route between Constantinople and India where the greatest benefit would be derivable from the substitution of railway for sea transit, whether regard be had to the rate of speed attainable or the economy with which the traffic might be worked.

A regular mail service being already in operation on the maritime portions of the Euphrates route to India—maintained, on the Mediterranean side, by French steam packets calling at Alexandretta, and between the ports of the Persian Gulf and Kurrachee and Bombay by the vessels of the British India Steam Navigation Company—a railway of little more than 900 miles in length, from Scanderoon (or Alexandretta), on the Mediterranean, to Kowait (or Grain), on the Persian Gulf, is all that is required to secure for us the immense political and strategic advantage of a complete alternative route to India; a shorter and more rapid route than now exists, and one, moreover, which compares very favorably with the Red Sea route, both as regards climate and the facility and safety of the navigation.

Both Alexandretta and Kowait, the proposed termini of the railway, possess all the requisites of first-class harbors.

The harbor of Alexandretta is one of great capacity; sufficient according to Sir John Franklin, Admiral Beaufort, and others, to contain the whole navy of Great Britain. It is the safest harbor on the coast of Syria, and might be made available for the purposes of the railway at a very small outlay. The place is, at present, open to some objection, on account of unhealthiness; but this, its only disadvantage, might be entirely obviated by drainage, at a moderate expenditure.

With regard to the harbor of Kowait, near the head of the Persian Gulf, Mr. William Parkes, who was, at my request, by the liberality of the Indian authorities, recently enabled to examine the ports in the Persian Gulf, states, in an able report addressed to me on the subject, that "nothing could be more secure or favorable in any way" (than Kowait) "for ships of the largest size, whether to ride at anchor, or to be moored alongside a quay wall." As a place for landing and embarking passengers, mails, and cargo, even without sea works more extensive than a short jetty to bring a steam tender alongside. Mr. Parks reportes that Kowait "was superior to Alexandria, to Suez, and to Bombay, before the completion of recent improvements; while, from an expenditure of from £80,000 to £100,000, a wharf of sufficient length to berth four steamers, of £3,000 tons each, might be constructed, and the railway brought down upon it, thus placing Kowait on a par, in this respect, with Suez (as it is), Brindisi or Dover." Kowait is already one of the most important towns in the Gulf, and, according to Captain A. D. Taylor, late of her Majesty's Indian Navy, possesses more baghalahs, or boats of the country, than any other port in the Gulf which trades with India; and there can be no doubt, if it be adopted as the eastern terminus of the railway, it will, within a very short period, have an enormous trade of its own, irrespective of the through traffic passing over the railway.

As regards the route which the railway should take between Alexandretta and the Persian Gulf, it is to be borne in mind that the great and primary object of the undertaking is the connection of the Mediterranean Sea and the Persian Gulf by railway; and, the necessity of such a connection having been once established, the precise line which the railway should take, would appear to be comparatively a matter of less vital importance. I may observe, however, that, passing in the first place from Alexandretta, the proposed terminus on the Mediterranean, to Aleppo, a great *entrepot* of trade, the route from that place to the Persian Gulf having much the strongest arguments in its favor would appear to be that recommended by Felix Jones, keeping on the right bank of the Euphrates for the whole distance, beyond the reach of inundations, and passing by way of Annah, Hit (the Is of Herodotus), the holy cities of Kerbela and Nedjef (or Meshed Ali), Semárwah and Súk-esh-Sheyukh to Kowait or Grain, on the Persian Gulf. This line would not pass many miles from Bagdad. This city and the neighboring holy places of Kerbela and Nedjef, are frequently chosen by Sheeah Mohommedans as a residence, that they may be buried by the side of Hoosein, their favorite saint, whose tomb at Kerbela is the peculiar object of their veneration, and is annually bedewed with the tears of thousands. The burialplace of Ali Nedjef, though of inferior sancity, is also held in great veneration. Pensioners of the Government of India, natives of the highest rank, frequently make Bagdad or Kerbela their adopted home; and, both from Persia and Hindustan, untold wealth has been poured into the coffers of the priests of Kerbela.

The route which I have traced from Alexandretta to the Persian Gulf—besides being, probably, the shortest line obtainable—would obviate altogether the necessity and expense of crossing the Euphrates. This line, moreover, regarded from a strategic point of view, would give the advantage of the interposition of two great rivers between the railway and an enemy advancing on the flank on which there would be the greatest likelihood of attack. The two termini, being on the open sea, would be, virtually under the guns of our ships, and the value of the island of Cyprus would be demonstrated as a *place de'arms.*

The opening up of the Euphrates route would afford an additional guarantee for the integrity of the Ottoman Empire; would tend, in a great measure, to a peaceful solution of the Eastern question; and would enable us more easily to discharge the grave responsibilities we have incurred in the virtual protectorate of Asia Minor. The proposed railway would consolidate the dominions of the Porte, by bringing the ancient Pachaliks of Aleppo and Bagdad into closer communication with the seat of Government. The grand impediment to the improvement of the Sultan's dominions is the want of means of intercommunication; and no line would promote more effectually their good government and prosperity, or do more to develop their really prodigious resources, than that which would lay open, to the energy and capital of the emigrant and merchant of the West, the extensive and fertile plains of the Euphrates and Tigris.

The cost of the most difficult portion of the railway, surveyed and estimated for by General Chesney and Sir John Macneill, and an engineering staff, was £7,500 per mile; my estimate has been higher, to make allowance for the fluctuations in the price of iron and other expenditure.

Let me recall for a moment to your notice the political inheritance said to be bequeathed by Peter the Great to his successors, in his will, whether genuine or apocryphal. "We must," says that remarkable document, which first became publicly known in 1837, "incessantly extend ourselves towards the north, the Baltic Sea, and towards the south, the Mediterranean. We must advance as much as possible twards Constantinople and India. Whoever shall reign there will be the true masters of the world. Therefore, we must face continual wars, sometimes with Persia; create dockyards and emporiums on the Black Sea; take possession, little by little, of that sea, as well as of the Baltic, which is a point doubly necessary for the success of the plan; hasten the downfall of Persia; advance into the Gulf of Persia, as far as can be done, re-establish through Syria the ancient commerce of the East, and enter into the two Indies, which are the stores of the world. When once there, we can do without the gold of England."

The policy of Russia has certainly been in accordance with the above.

The old southern boundary of Russia in Central Asia extended from the Ural, north of the Caspian, by Orenburg and Orsk, to the old Mongolian city of Semipolatinsk, and was guarded by a cordon of Cossack outposts. In 1716, Peter the Great sent a force, commanded by Prince Beckovitch, to take possession of part of the eastern shore of the Caspian. Three forts were then built, though subsequently abandoned, after an unsuccessful expedition against the Khivans. More recently, since 1834, Russia has succeeded in firmly establishing herself on the eastern shore of the Caspian, where she has now four permanent posts: Fort Alexandrovsk, Krasnovodsk, at the mouth of the Balkan Gulf, Chakishlar, at the mouth of the Attruck, and the Island of Ashurda. To the east she has crossed the Kirghis Steppe, and established herself on the Sir Daria or Jaxartes, which Admiral Boutakoff is said to have navigated for 1,000 miles in 1863. Thus the Russian frontier in Central Asia has been pushed forward, until her advanced posts on the east look down from the Tian Shan range upon the plains of Chinese Turkestan.

In Western Turkestan, also, she has gradually extended her boundary; and has annexed or subjected Tashkend, Kokan Khojund, Samarcand, Bokhara, and Khiva. In thus pursuing her career of annexation, Russia but follows the natural policy of a great military empire; being forced, moreover, as Sir John Malcolm said, by an impelling power which civilization cannot resist when in contact with barbarism. And thus is her influence established on the Oxus and Jaxartes. The Oxus, or Amu Daria, is a noble river, not easy of navigation, but it is believed, capable of being made so. It will furnish a ready means of carrying the tide of Russian annexation eastward until it finds a barrier in the Hindoo Koosh. When Russia shall have established herself along the Oxus, her position will be at once menacing to Persia and India. From Chardjuy on the Oxus, there is a road to Merv, distant about 150 miles, and from Merv a direct road runs along the Valley of the Murghab to Herat, the so-called "key of India." Merv is, historically, a part of the Persian Empire, but, in these countries, it is notoriously difficult to define boundaries with any presision. Should Russia succeed in occupying Merv—as there is too much reason to fear that she ultimately will—and in converting the neighboring tribes into friends or allies, her position would be one which would necessitate still greater vigilance on our part.

Surely in the face of such facts as these, the time has arrived when England should rouse herself from the apathy of the past, and take steps to secure the incalculable advantages which would accrue to herself and her Eastern dependencies from the opening up of the Euphrates route, which would threaten the flank and rear of any force advancing towards India.

The subject, important as it is in its bearing on the power and stability of the whole British Empire, is one of absolutely vital moment to India; but it should not be forgotten that all our Eastern possessions would participate in the benefits which would accrue from the establishment of the Euphrates route.

There is ample reason to believe that the proposed undertaking would prove remunerative at no distant date; at the same time, the results sought are far more important than those which are usually looked for in a pecuniary investment. Why should we not regard the Euphrates Railway as the French have regarded the Suez Canal? In the words of a recent writer:—

"Nations may receive much larger returns for judicious outlay than any to be commonly looked for by shareholders; for the results in material prosperity to be derived by a community from augmented facility of communication, from moral and political progress, and, above all, from an increased security for peace, far transcend in value any conceivable amount of dividends, and should be taken into account in determining as to the propriety of lending Governmental assistance in particular instances."

The general features of the projected Euphrates Valley Railway may be thus briefly summed up:—

1. It would connect the Mediterranean with the head of the Persian Gulf, between which and Kurrachee and Bombay regular communication is now maintained by a line of powerful steamers, subsidized by the Indian Government.

2. Making Kurrachee the European port of India in place of Bombay, it would save about 1,000 miles in the distance between England and India, and would reduce the time occupied in the journey by several days.

3. It would render it possible to maintain India with a smaller European garrison than is now necessary, and would thus reduce our military expenditure.

4. It would save the Government large sums, in sudden emergencies, by the facilities it would afford—and that at all seasons of the year—for the transport of troops and stores.

5. It would enable troops from England to be landed at Kurrachee in about 14 days, and in two or three days more at Lahore, Peshawur, or Delhi.

6. It would subject an enemy advancing towards the north-western frontier of India to easy attack in the flank and rear, and would render the invasion of India all but impossible.

7. It would render the resources of England so promptly available in the

East that any hostile movement directed against us, whether from within or without our Indian frontier, might thus be effectually checked before it could assume formidable proportions.

8. It would give our extensive military establishments in India a direct influence in support of our power and prestige in Europe.

9. It would give England the first strategical position in the world.

10. It would facilitate the protection of Asia Minor by England.

11. It would relieve Persia from the predominating influence of Russia, by giving her access to a port on the Mediterranean.

12. It would be easily defensible by England, both of its termini being on the open sea.

13. It would be protected, on the flank most likely to be assailed, by two formidable rivers, the Euphrates and Tigris.

14. The length of the railway from Alexandretta, on the Mediterranean, to Grain, on the Persian Gulf, would be about 920 miles.

15. The country is admirably adapted for the construction of a railway, and the cost of the line is estimated at from £8,000 to £10,000 per mile.

16. The capital which would be required would thus be under 10 millions.

The military and political value of the Euphrates line is a matter of extreme moment, and has a far more decided bearing on the defense, not only of Turkey, but of Persia, and the whole district lying between the Mediteranean, the Caspian, and the Indian Ocean, than might at first be supposed.

So long ago as 1858, Field-Marshal Lieutenant Baron Kuhn Von Kuhnenfeld, Austrian War Minister, predicted that Russia would, in future, probably, try to satisfy her craving for an open seaboard by operating through Asia:—

"She will not," says this distinguished authority, "reach the shores of the Persian Gulf in one stride, or by means of one great war; but, taking advantage of Continental complications, when the attention and energy of European States are engaged in contests more nearly concerning them, she will endeavor to reach the Persian Gulf step by step—by annexing separate districts of Armenia, by operating against Khiva and Bokhara, and by seizing Persian provinces. * *

"The most important lines which Russia must keep in view for these great conquests are—

"1. The line from Kars to the Valley of the Euphrates and Mesopotamia.

"2. That from Erivan, by Lake Van to Mossul, in the Valley of the Tigris, to Mesopotamia, and thence, after junction with the first line, to Bagdad.

"3. That from Tabrez to Schuster, in the Valley of the Kercha, where it joins.

"4. The road leading from Teheran, by Ispahan, to Schuster, and thence to the Persian Gulf. * * *

"Once in possesion of the Euphrates, the road to the Mediterranean, *via* Aleppo and Antioch, and to the conquest of Asia Minor and Syria, is but short.

"It is clear that all these lines are intersected by the line of the Euphrates, which, running in an oblique direction from the head of the gulf north of Antioch to the Persian Gulf, passes along the diagonal of a great quadrilateral, which has its two western corners on the Mediterranean, its two eastern on the Caspian and Persian Seas, and so takes all Russian lines of advance in flank.

"From this, it is evident that the secure possession of the Euphrates line is decisive, as regards the ownership of all land lying within the quadrilateral. It must, therefore, be the political and strategic task of Russia to get the Euphrates line into her hands, and that of her enemies to prevent her doing so at any cost.

"The great importance of a railway along this decisive line, which connects Antioch with the Persian Gulf, follows as a matter of course. It is the only means by which it would be possible to concentrate, at any moment, on the Euphrates, or in the northern portion of Mesopotamia, a force sufficiently strong to operate on the flanks of the Russian line of advance, and stop any forward movement. * * *

"It is true that, at first, the aggressive policy of Russia in the East will only threaten the kingdoms of Turkey and Persia; but, as neither one nor the other, nor both combined, would be strong enough, without assistance, to meet the danger successfully, England must do so; and it is certain that she must, sooner or later, become engaged in a fierce contest for supremacy with Russia.

"The Euphrates Valley Railway becomes, therefore, a factor of inestimable importance in the problem of this great contest. Even now, the construction of the line will counteract the Asiatic policy of Russia, for it will strengthen the influence of England in Central Asia, and weaken that of Russia.

"The growth of Russia in the East threatens, though indirectly the whole of Europe, as well as the States named above; for if she were firmly established in Asia Minor the real apple of discord, Constantinople, would be in imminent danger, all the commerce of the Mediterranean would fall into her hands, and she would command the canal through the Isthmus of Suez.

"Whatever the commercial value of the Suez Canal to Central Europe, there is no doubt that it is secondary in importance to the Euphrates Railway, which affords the only means of stemming Russian advances in Central Asia, and which directly covers the Suez Canal."

Looked at in every light, historically, politically, and commercially, the proposed restoration of the ancient route of the Euphrates, throwing open the portals of the East to the commerce of the world, and to the arts, the sciences, and civilization of the West, in an interesting and noble design, fraught with consequences of the highest moment to the destinies of our race.

To plant industry and the arts where indolence and barbarism have hitherto prevailed—to hasten the day when the breath from the four winds, as foreshadowed by the prophet, will breathe upon the slain, and the dry bones will live; when "the wastes shall be builded, and the desolate land shall be tilled," and men shall say, "this land that was desolate is become like the Garden of Eden, and the waste, and desolate, and ruined cities are become fenced, and are inhabited." "So shall the waste cities be filled with flocks of men."

To accomplish this noble undertaking is the mission of England. Its fulfill ment has already been too long delayed. Another nation, as Lord Beaconsfield, some years ago, took occasion to remind us, is slowly, but surely, extending her power eastwards, and is gradually establishing a footing in military positions, from which she can at once menace our empire in the East, and diminish our power and prestige among the nations of Europe; and I would close this paper by urging my conviction, that if we continue to neglect securing the establishment of the Euphrates route under the auspicies of Great Britain, we shall speedily find that the shortest, easiest, and safest route to our Eastern possessions has fallen into the hands of our most powerful rival for commercial and political ascendancy in the East.

THE HARDENING OF IRON AND STEEL.

By Professor RICHARD AKERMAN, Stockholm.

From "Engineering."

Hardening has, as is well-known, been employed from time immemorial in order to make steel hard, but it is also a long time since it became known that the strength and tenacity of iron could be increased by the same operation. The knowledge of the effects of hardening, especially on iron, is, however, by no means so complete, and still less so generally diffused, as is desirable. This question has, besides, acquired increased interest through the Paris Exhibition, and above all from the Terrenoire exhibit of Siemens-Martin castings of extraordinary strength, and free from blowholes; and as at the meeting of the Iron and Steel Institute in Paris I ventured to give expression to the view that the reason why the strength of undrawn Martin castings may be equal to that of drawn ingot-metal of the same degree of hardness, must be sought for in the compression induced by the hardening, I have considered it to be my duty to endeavor to explain the reasons of this in greater detail. For this purpose, however, it is necessary in the first place that we endeavor to make ourselves acquainted with the nature of hardening.

THE DIFFERENT MODES OF OCCURRENCE OF CARBON IN IRON.

Commonly the carbon occurring in iron is separated only into two principal varieties, viz., graphite and combined carbon, the latter of which is differently named—by some dissolved and by others amorphous carbon. The graphite found in iron is, as is well known, carbon in a quite distinct form, or, in other words, only mechanically incorporated with the iron, and it is accordingly obtained as such when pig iron is dissolved in an acid. The so-called combined carbon, on the other hand, when the iron is dissolved in boiling hydrochloric acid, escapes as carburetted hydrogen if proper attention be given to the dissolving process, so that the boiling commences almost immediately after the addition of the iron to the hydrochloric acid, and is continued uninterruptedly for a sufficient length of time without access of air. If the iron, again, be dissolved in cold hydrochloric acid, which is only warmed after a little, a part of the so-called combined carbon also in general remains as a black residue, and this is apt to be the case in a still greater degree if the air has had readier access, for in that case it appears that humus-like substances may be formed by its action on a part of the combined carbon. More or less of the combined carbon remains as an undissolved residue according to the different ways in which the solution is carried on, and its being completely driven off can be reckoned on with certainty, only provided the solution proceeds in acid which is brought immediately to continuous boiling, without access of air in the way first described. M. Caron, and after him Herr L. Rinman, have, moreover, further discovered that the quantity of carbon remaining undissolved when steel is dissolved in cold hydrochloric acid may be very different, according as the same steel was differently treated before dissolving. Thus, raw steel undrawn on being dissolved in this way gives a much larger residue of undissolved carbon than the same steel when rolled, and the latter more than when it is drawn out under the hammer. Finally, this residue of carbon approaches to none at all in the well-hardened steel. If this well-hardened steel be heated anew, it yields again a large residue of undissolved carbon, and this in a degree proportioned to the duration and intensity of the heating.

These facts undoubtedly indicate that the so-called combined carbon does not occur in the iron always in the same way, and as we have every reason to suppose that the carbon was in more intimate union with the iron in the same proportion as it was, on the solution of the iron being carried out in the same way, the more completely driven off as carburetted hydrogen, and the less it was separated as carbon, it appears that we may conclude from these circumstances that drawing, and, above all, hardening, cause a more intimate union between the iron and the carbon, this union, on the other hand, being again relaxed by the renewed heating and subsequent slow cooling of the iron. It thus appears that the carbon commonly called combined ought properly to be divided into two kinds: viz., first, the carbon most intimately combined with the iron, which we, in accordance with Rinman's proposal, shall call hardening-carbon, inas much as it characterizes the well-hardened steel; and, further, the carbon incompletely combined with the iron, which may be said to be in a sort of passage to graphite, and which Rinman called cement-carbon, because it occurs in largest proportion in the undrawn raw or cement steel.

If we now inquire what the circumstances are on which it depends whether more or less of the so-called combined carbon in a malleable iron or steel exists as hardening or cement-carbon, it immediately appears that the latter is changed into the former by a heating to a red heat, succeeded by a violent forcing together, continued until cooling is almost complete; while hardening-carbon, on the other hand, is changed into cement-carbon by long-continued heating, followed by slow cooling without extra compression. In order to show that iron and carbon may be combined by pressing together more easily than otherwise, Caron, upon an anvil covered with charcoal in fine powder, hammered out quickly a strongly heated piece of iron, which in this way was steeled on the surface, while another piece of the same iron heated as strongly, which was imbedded in similar charcoal powder, and allowed to cool in it without hammering, d.d not show the least sign of steeling.

In the case of strong hardening of hard steel, we have the most powerful compression, for the rapid cooling produces a great difference of temperature between the outer and the inner layers of the piece, the more cooled exterior layers compressing the interior with greater force in proportion, partly as the latter are expanded by being more strongly heated, and partly as the limit of elasticity of the substance is high, so that there is not too great a loss of the compressing force by the extension of the exterior layers. Again, that hammering favors the conversion of cement-carbon into hardening-carbon, or the more intimate union of the carbon with the iron in which it occurs, more than rolling, may at least occasionally to some extent be attributed to the more powerful compression exerted by the hammer, but still more to the circumstance that the iron or steel, when the rolling is ended, commonly has a far higher temperature than when it has been drawn out under the hammer. For if the iron or steel be still red-hot when the drawing is finished, a part of the carbon converted into hardening-carbon, or more intimately united with the iron during the compression to which it has been subjected, may be again changed into cement-carbon during the succeeding slow cooling.

There is thus a very complete correspondence between the occurrence of hardening and cement carbon and their mutual conversion in malleable iron and steel on the one side, and the relations of the combined carbon and the graphite in pig iron on the other. It is, however, not improbable that the so called combined carbon may occur in pig iron also in two ways. A grey but not too siliceous pig may, as is well known, be converted into white pig iron by melting, followed by sufficiently rapid cooling, as by casting in thin plates in a form adapted for rapid cooling; or, if the rapidity of cooling be not sufficiently great in this way, by so-called granulating in water, or some yet more rapid mode of cooling. On the other hand, a white pig, somewhat rich in carbon, but not containing too much manganese or sulphur, may, by melting and superheating, followed by casting in a heated mould which cools with sufficient slowness, be converted into gray pig iron. But in order to change to gray a white pig of the nature described above, it is quite unnecessary to remelt it; for the greater part of its combined carbon may also be converted into graphite merely by a sufficiently long-continued heating to a strong yellow heat, air and other oxidizing substances being excluded.

Graphite as such cannot be found in the molten pig, for it must then, in consequence of its comparatively low specific gravity, rise to the surface of the bath of pig iron, and form a deposit there, which, as is well known, happens very frequently; but in such a case this graphite is found not in, but upon, the pig iron. It thus follows that the graphite to be found in solidified pig iron has not been able to separate itself sooner than immediately after solidification, and whether a pig becomes gray or white depends, besides the presence of other substances in the iron, just upon the rapidity of cooling at or immediately after solidification. But this again depends greatly on the degree of superheating of the pig iron when it is cast in a certain form, for the more super heated the pig iron then was, so much more heat has the mould been able to take up before solidification commences, and the slower consequently is the succeeding cooling. Thus also it is only by a long-continued heating to a temperature approaching somewhat closely to the melting point of pig iron that the white pig may, without remelting, be converted into gray; but if the temperature be raised still further, so that fusion commences, the graphite which has been separated from the iron is again dissolved in it, for otherwise it would naturally rise to the surface. It is on this, too, that it must depend that the fusion point of the gray pig is only about 100° C. higher than that of the white, and thus so incomparably lower than the fusion point of steel or malleable iron, which have the gray pig's content of combined carbon, but altogether want its graphite.

As in pig iron, with strong and long-continued heating, carbon is separated in the form of graphite, so heating, followed by slow cooling, favors the formation of cement-carbon in steel. On the other hand, by the rapid cooling of the molten pig and the violent contraction thus occasioned, the content of combined carbon in the iron is increased, and in the same way a rapid cooling or violent compression otherwise attained causes in the graphite-free steel a more intimate union of the cement-carbon with the iron, or its conversion into hardening carbon. The difference is only that the mutual conversion of cement and hardening carbon may begin at a comparatively low temperature, while the conversion of graphite into combined carbon and the reverse process can only take place at a temperature approaching pretty close to the melting point of pig iron; for after a gray pig has cooled to a red heat, the final cooling may be as rapid as possible, without the content of graphite being thereby diminished; and in the same way, at a temperature no higher than a red heat, a white pig cannot be converted into a gray.

The properties of a pig iron, almost free from other substances than carbon, are properly dependent on the content of combined carbon, and graphite exerts an influence upon it only so far as it diminishes the continuity of the iron molecules, and thereby lessens the strength; to which may be added that, as we have seen, it may, by the use of proper methods, be converted into combined carbon, which then exerts its usual great influence upon the iron. Just the circumstance that the important fact now stated is generally overlooked is the reason why we so often meet with the incorrect statement, that the influence of carbon on pig iron is quite different from its action on malleable iron and steel. It is easy to prove the contrary if we distinguish properly in pig iron between the combined carbon and that which is only mechanically incorporated as graphite, which, of course, ought not to be included in the calculation in any higher degree than as stated above, if we wish to form a judgment of the properties of pig iron as dependent on its content of carbon.

As the cement carbon cannot, as has been shown above, be so intimately combined with the iron as the hardening carbon, but approaches in some degree to graphite, the supposition is easily arrived at, that the cement-carbon cannot have so great an influence on the properties of iron as the hardening carbon; and there are very distinct indications of this, as will be seen from what follows, but until hardening and cement-carbon can with certainty be distinguished, and some method has been discovered of quantitatively determining each of them, it is, of course, still too early to say anything with certainty on this point. In the near future the requisite light will certainly be thrown on this point also, and we will then probably see that some of the great changes in iron and steel which have been induced only by different methods of treating the same material, are caused by the alterations in the proportions between hardening and cement-carbon brought about by the method of working.

Methods of Hardening.—Proceeding now to the hardening, we find that experience has sufficiently shown that its effect mainly depends upon the content of combined carbon in the iron, upon the differences of temperature between the iron or steel and the hardening fluid, and further on the rapidity of the cooling. The last-mentioned, again, is dependent on the quantity of the hardening fluid, its specific gravity, power of conducting heat, specific heat, boiling-point, and heat of vaporisation. Of the four liquids, mercury, water, oil, and coal tar, therefore the first-named hardens much more powerfully than oil, and oil more powerfully than coal tar. Further, the hardening power of water is altered not only by differences of temperature, but also by the addition of different substances which change its properties in the respects just mentioned. Finally, the rapidity of cooling, so important for the degree of hardening, is also dependent on the way in which the piece is held down into the hardening fluid. For if it be kept still in a hardening fluid of low specific gravity and small conductivity and specific heat, the quantity of the hardening fluid is not of the same importance as if the piece be unceasingly moved about in it; but in the latter case the cooling of the piece is apt to be unequal, inasmuch as by the moving about the front parts are cooled somewhat more rapidly than the back ones. This is also the case if by hardening in running water we make the quantity of the hardening fluid, so to speak, unlimited. The front part of the piece, or that which is termed up-stream, is then, of course, cooled most rapidly; and in order in such a case to attain an even hardening, it is necessary to turn round the piece rapidly and unceasingly.

The layer of steam which, in the case of hardening in a substance so easily converted into vapor as water, is formed around the warm piece is an obstacle to the cooling along with the degree of hardening which is dependent upon it; but if care be taken that in one way or another the steam be easily and rapidly carried away as it is formed, the rapidity of cooling, on the other hand, on account of the great heat of vaporization of water, is very considerably promoted by this conversion into vapor. Small pieces, therefore, are also very well hardened in water dust finely distributed by means of a stream of air or steam; and the highest degree of hardening may, according to Herr Jarolimek, be attained in this way with so moderate a quantity of water that all the water dust which comes in contact with the warm piece is brought by it into the form of steam. These influences, exerted by the formation of steam, must also be taken into consideration when, in order to attain an inferior degree of hardness, warm water is used instead of cold. It cannot accordingly be denied that there are many factors exceedingly difficult of calculation which exert an influence on the speed of cooling, and thereby on the degree of hardness. Nor is it much to be wondered at that mistakes are readily committed in hardening, and that great practice is required in order to be able confidently to reckon on a certain effect; and, finally, that a workman accustomed to hardening considers that only a single method which he has been in the habit of employing can be used for a certain purpose, while another equally skillful workman can only attain the same result by a method essentially different.

It further appears that the rapidity of the first cooling, from the 600 deg. to 700 deg. C., to which steel has commonly been heated, to 300 to 400 deg. C., has a manifold greater influence on the degree of hardness than the succeeding cooling. Thus, the just mentioned Herr Jarolimek has shown that steel wire may be very well hardened both in watery vapor and in molten tin, lead, and even zinc, though the last-named metal does not melt under 400 deg. C., while the cooling of the same steel wire from 300 deg. or 400 deg. to 0 deg. C. does not cause any true hardening, however rapidly it may proceed. In order that steel wire may be hardened in this way, it is not, however, allowed to remain any considerable time in the molten bath of metal, for, by long-continued heating following such a hardening the degree of hardening is afterwards diminished more and more. If it be taken out again after being dipped in the bath for quite a short time, and afterwards allowed to cool in the air, the degree of hardening for small articles is equal to that attained by ordinary hardening with the tempering following upon it.

The Effects of Hardening.—Of the effects produced by hardening, it was in old times mainly the hardness on which attention was fixed, and from this is derived the old saying that a substance does not take hardening if it do not thereby become so hard that a common file can no longer exert any noteworthy influence upon it. From time immemorial a distinction has also been made between iron steel in this way, that the former, with common hardening in water, is not hardened in the sense just indicated, while steel, on the contrary, is hardened. Since the Bessemer process came into use, however, the old idea of steel has had too often to give way to the desire to denote with the appellation steel all such iron is in the finally refined state has been completely fused, whether it "takes temper" or not. In accordance with the proposal unanimously made by the International Committee, nominated at the Philadelphia Exhibition, Germany, Austria, and Sweden have universally retained the old idea of steel, at the same time, however, that an exact distinction is made between those varieties of iron and steel which, in a finally refined state, have been completely fused and those that have not been so, the former being named ingot iron and ingot steel, and the latter weld iron and weld steel. In Great Britain, the United States, France and Belgium, on the other hand, there has not been the same unanimity, and hence arises the lamentable uncertainty which now often prevails, when, for instance, a soft steel is spoken of, for by this one may understand a soft ingot iron, which, by hardening, never becomes properly hard, and another a true steel, which, however, is not harder than that it just "takes temper."

We sometimes hear it brought as an objection against the old way of distinguishing between iron and steel that it is difficult to determine whether a piece, after common hardening in water, is to be considered as having taken true hardening or not. But such a reason is in fact quite unwarranted, because, according to the old view, only the varieties approximating most closely to each other of the hardest iron and the softest steel can be mistaken for each other, and such a mistake is indeed of little importance when compared with the great mistake just referred to of soft iron for soft steel. If it be wished wholly to avoid the possibility of making mistakes between hard iron and soft steel, this even ought to be attained very easily by the method of determination, in which a sharp edged splinter of a certain mineral —felspar, for instance—scratches iron, although, after being heated to a moderate red heat, it has been suddenly cooled in cold water, while steel, after similar treatment, cannot be scratched by the same material.

The substance which exerts the greatest influence on the increase of hardness by a certain hardening process is the content of combined carbon in the iron. Iron completely free from carbon is, even after hardening in mercury, as soft as before, and an otherwise pure iron, with at most two-tenths per cent. carbon, does not become very much harder by hardening; but, on the other hand, as the content of carbon increases, the difference in the degree of hardness before and after hardening increases more and more, so that the boundary line between iron and steel lies in general at a content of carbon of about 0.4 per cent., this depending, however, upon the iron's content of certain other substances, which, as we shall soon see, also exercise some influence on the degree of hardness.

In the closest connection with the increase of the hardness, stand the raising of the limit of elasticity, and the breaking strain or ultimate tensile strength and the diminution in ductility. Unfortunately the researches that have been carried out regarding these points are not yet numerous enough to enable us with figures to express completely all the changes in these respects which are caused by hardening in iron and steel with different contents of carbon, but sufficient experiments have already been made to give us somewhat satisfactory ideas on this point. A comparison between the Tables I., II. and III., shows that the effect of hardening is in general less in the case of weld iron, loose or open in its texture, than in that of the dense or compact ingot iron; but in proportion as the former even is denser or freer of cinder, hardening has a greater effect upon it, as is shown by a comparison both of the more compact Lesjöfors iron with the other sorts of iron refined in the open hearth, and of the more compact Surahammar with the other sorts of puddled iron, all in Table II. In order to augment considerably the strength of ordinary puddled iron, the French iron manufacturing company, La Compagnie de l'Horme, increases the hardening power of water by adding to it sulphuric acid the cooling effects of water is thereby raised, and thus also its hardening power; but in order to prevent the corrosion and rusting of the iron, it would be advisable to endeavor to attain the same result in some other way, as by the addition of some salt that would have less corrosive action upon the iron. The following little table shows the mean results of breaking tests of puddled iron from Buère, part unhardened and part hardened in the dilute sulphuric acid.

"FER ORDINAIRE."

Unhardened.		Hardened in Dilute Sulphuric Acid.	
Breaking Weight.	Elongation per Cent.	Breaking Weight.	Elongation per Cent.
kilo. per sq. mm.		kilo. per sq. mm.	
38	17.5	41	20

"Fer Fin."

Unhardened.		Hardened in Dilute Sulphuric Acid.	
Breaking Weight.	Elongation per Cent.	Breaking Weight.	Elongation per Cent.
kilo. per sq. mm. 37.7	23.8	kilo. per sq. mm. 48.2	14.8

The ductility, so far as it is indicated by the elongation and contraction of the area of fracture, is indeed generally diminished by hardening even in the soft varieties of iron; exceptions, however, are to be found to this rule, and this appears to be specially the case with the more phosphoriferous iron, the resistance of which to breaking, elongation, and contraction of the area of fracture, may even be increased by hardening, as for instance is the case both with the iron from Aryd made by refining lake ore pig iron in the open hearth, and with the most phosphoriferous of the varieties of puddled iron from Buère which have just been mentioned. This is, besides, confirmed by several other facts; as for instance that Martin iron with 0.15 per cent. phosphorus can stand much severer bending tests after hardening than in an unhardened state.

In order to obtain a somewhat satisfactory idea of the ductility of a substance, we ought not, however, to fix our attention exclusively on the breaking elongation and the contraction of the area of fracture, but also to pay due regard to the ratio of the limit of elastic strength to the breaking weight. For the smaller this ratio is, the greater force beyond the limit of elasticity, can the substance resist without fracture, and tougher accordingly it is. To this ratio more attention ought doubtless to be given than is commonly the case, the rather because it is possible to get very different values for the limit of elasticity of a certain substance, according to the different ways in which the breaking tests are carried out. For the more it is sought to carry out the tests so that they shall give a high limit of elasticity, the greater, and therefore the more disadvantageous for the ductility, does the ratio of the limit of elasticity to the breaking weight become; and for those who lay sufficient weight on this point, there is a self-acting retribution if, in order to be able to boast of a high limit of elasticity, it is determined in some unfair way, as is sometimes the case.

In this connection there is also, perhaps, reason to point out another too common impropriety in breaking tests, viz., the different ways in which the breaking elongation is estimated. This elongation is of course greatest in the neighborhood of the place of fracture, where the sectional area is most diminished. The most thorough-going method, therefore, is to exclude the whole of the elongation in the neighborhood of the place of fracture, as Herr Styffe has done (see Table II.) in the case of the hardened samples, and limit attention wholly to the much smaller percentage of elongation which the other parts of the bar have undergone. In this way there are of course obtained very small percentages of elongation, which cannot be compared with those found when the elongation at the place of fracture is included in the calculation. On the other hand, the advantage is gained by the first described method that we are somewhat independent of the length of the test bar, which by the other method is by no means the case. For it is certain that the longer the test bar is, the less influence will the elongation at the place of fracture have in the calculation of the whole percentage of elongation. The shorter the test bar is, on which the greater elongation at the place of the fracture is divided, the more considerable on the other hand does its influence become, and thus the greater or more advantageous does the percentage of elongation appear. It ought, therefore, when, as is commonly the case, the elongation at the place of fracture is included in the calculation, never to be left unstated on what length of test bar the elongation percentage is reckoned; but the sectional area of the bar ought besides to be included in the calculation, for the larger it is, the greater is the elongation of a certain iron in the neighborhood of the place of fracture.

In order to be able to boast on paper of a comparatively great percentage of elongation, it is only necessary to carry out breaking tests on short and thick bars, and such tricks are, in consequence of the too common ignorance of purchasers of iron, unfortunately not at all uncommon. However, there is some help to be had even in this respect by giving proper attention to the ratio of the limit of elasticity to the breaking weight. For if this ratio be large, while the length and sectional area of the test bar are not stated, we have reason to suppose when the breaking elongation notwithstanding has been stated to be comparatively large, that it has been determined in a too favorable manner, and that the ductility of the material is, therefore, in fact not so great as would appear from the percentage of elongation alone. It is clear from this that a closer correspondence in the dimensions of test bars is very desirable, but so long as great variations occur in them, the greatest caution, as has been already observed, must be used in comparing statements from different testing establishments, which is also to be observed in making comparisons between the tables given with this paper.

If we now inquire what influence the hardening has upon the oft-mentioned ratio of the limit of elasticity to the breaking weight, we find in Table I., that the comparatively pure ingot iron has by hardening become much tougher, for although the limit of elasticity has been thereby increased on the average of 30 tests of 15 different sorts of Bessemer iron from 20.8 to 25.7 kilogrammes per square millimetre, the breaking weight has increased in a still greater degree, the consequence of which is that the ratio of the limit of elasticity to the breaking weight of these pure sorts of Bessemer iron has been diminished by the hardening on an average from 0.502 to 0.398. So great an increase of toughness by hardening, however, is by no means everywhere common, but is perhaps mainly dependent on the purity of these Swedish varieties of iron being greater than is common in other countries. On the contrary, the ratio of the limit of elasticity to the breaking weight appears to be in general somewhat increased by hardening. This is the case among others with the tests given in Table III, of drawn Martin metal, excepting, however, the most phosphoriferous, whose toughness was increased by hardening, while the ratio of their limit of elasticity to the breaking weight was diminished from 0.627 to 0.559.

The last-mentioned fact yields a further proof both of a special beneficial influence that the hardening has on the phosphoriferous iron, to the probable causes of which we shall return below, and of the importance of giving proper attention to the ratio of the limit of elasticity to the breaking strain, for in the unhardened metal the three most phosphoriferous samples in the Table referred to show the highest figures for the oft-mentioned ratio, but at the same time these are the only ones in which it is diminished by hardening. The other corresponding figures in this Table have, on the contrary, been increased. In other words, the toughness of the more phosphoriferous, like that of the purest iron, as shown in Table I., has been increased by hardening, but the toughness of the others, and especially of the steel, has been diminished by the same process. This diminution in toughness is, however, not very noteworthy in the case of the iron, the rather because it depends more on a special raising of the limit of elasticity than on any deficiency in the increase of the ultimate tensile strength, and the strength of these sorts of iron may nevertheless be said to have been considerably increased by the hardening.

Table III. further confirms the long-known fact that a large content of manganese is apt to make the steel go in pieces in hardening.

Hitherto we have only considered the influence of hardening upon iron, but if we now proceed to investigate its action on steel, we find that it is shown chiefly by an increase in its hardness and a diminution in its ductility greater in the same proportion as the steel is richer in carbon and the hardening fluid employed is more powerful in its action. At the same time that steel with an increased contents of carbon, becomes through a certain hardening all the harder, it becomes thus at the same time more brittle; and in the closest connection with this is the fact, that in the hard steel rich in carbon the limit of elasticity is increased by hardening much more than the ultimate tensile strength, so that these in the strongly hardened hard steel even coincide. Provided the method of hardening is adjusted to the degree of hardness of the steel, so that it is less powerful in the same proportion as the content of carbon in the steel is greater; it may, however, be asserted that the breaking weight is increased by hardening, even in the case of steel; but if the hardening be too strong, the ultimate tensile strength of hard steel is thereby diminished quite rapidly, as Table II. clearly shows; or the steel breaks in pieces of itself either during the hardening or a short while after, as is seen in table III.

It is, as is well known, on account of this brittleness or deficient ductility that the hardened steel is usually tempered or heated to 200 deg. or 300 deg. C., for thereby its ductility is somewhat increased, but its hardness at the same time also diminished. This is the case most of all with the outer layer, which of course is that which it is desired should be hardest, and to avoid this and the trouble and loss of time connected with the process just mentioned, the hardening itself is sometimes instead so modified that its effect is equal to that of a more powerful hardening, followed by tempering. For such a method, however, more than common skill and practice are required, and it is therefore comparatively seldom used. For attaining this end there is sometimes used a less powerful hardening fluid, and sometimes a warm instead of a cold fluid, and sometimes the piece is held only a short time in the hardening fluid, and is taken out while it is yet warm in its interior, and allowed finally to cool in the air. Further, the material may, for this purpose, be heated more gently, but it must be kept in mind in connection with this that a less heat than a little red heat (cherry red) in general does not induce any proper hardening; and, on the other hand, that tool steel cannot in most cases be heated to a higher temperature than that just indicated without running the risk of becoming by hardening quite too brittle. It is thus properly only for soft steel and iron that the degree of heating can be varied to a greater extent, but it holds good specially for the latter, and, above all, for weld iron, that the temperature must be considerably higher than for hard steel, if the proper action of hardening is to be attained.

The more strongly and the longer that the iron or steel after hardening is again heated with slow cooling supervening, the more completely are the effects of hardening removed; and care ought, therefore, as is well known, to be taken in tempering; but here we have, however, a good help in the different colors of tempering which follow one after the other.

On the appearance of fracture also the hardening has an influence, the grain becoming finer.

THE INTIMATE CAUSES OF HARDENING.

After having now discussed in detail the effects of hardening on the different varieties of iron and steel, we shall now, in conclusion, endeavor to ascertain the intimate causes of these effects. That they increase with the rapidity of cooling, and thus are a consequence thereof, has been already shown, but the question is how the rapidity of cooling can produce such effects. The hypothesis that is still most common is that which assumes that a rapid cooling gives us the *status quo*, or the state into which the substance was brought by the heating which immediately preceded the rapid cooling, and the action of the hardening would in such a case only be a result of the heating itself, inasmuch as the rapid cooling only, so to say, fixed the warm condition, or, in other words, made it possible for the substance, even in a cold state, to show itself as it was during the heating. During slow cooling, on the other hand, the molecules would have opportunity to group themselves in a more crystalline manner, and hence the coarser grain. But if the molecules can move about in this way during the cooling, they may well do so to a still greater extent at the highest temperature to which the substance has been heated, for this grouping of the molecules is rendered possible just by the softening to a greater or less degree which the heating causes in the iron, and the softening is naturally greater the higher the temperature is.

As it has now been discovered that various crystallized precious stones may be artificially produced, and that the main condition for this is to keep the requisite raw materials uninterruptedly for a long time at a certain high temperature, and afterwards allow them to cool slowly, but that this object, on the other hand, can certainly not be attained by merely heating the materials quite hastily to the same temperature, and afterwards allowing them to cool slowly, the time appears also to be come for abandoning the view that the slow cooling from a certain degree of heating produces a disposition to crystallization that did not exist at the highest temperature. Another striking proof of the unwarrantable nature of this view also is to be found in the fact already stated, that a white pig, poor in manganese and sulphur, but somewhat rich in carbon, may, by sufficiently long-continued heating to a yellow heat, be converted without fusion into gray. Such a change, on the other hand, is not produced merely by a short heating to a yellow heat with slow cooling supervening, and it is therefore clear that it is not so much the slow cooling as the continuous intense heating which brings about the molecular change in question.

The too common view of the *status quo* cannot thus in this case be maintained, but instead a satisfactory explanation of the phenomena of hardening appears to be obtained by supposing that the compression on forcing together of the substance dependent on the rapidity of cooling produces the changes in it which are brought about by hardening. The reasons for the correctness of this view are, as we shall now see, many and striking.

That, first of all, a violent compression must in such a case take place is self-evident, for we have now to do with a body heated from without, which, therefore, at least when the heating has not been of all the longer duration, is apt to be warmer in the outer than in the inner layers. When now this body by dipping in a hardening fluid, or in some other way, is exposed to a rapid cooling action from without, the outer layers are cooled first, and the difference of temperature between the outer and the inner layers is greater the whole way through in the same proportion as the method of cooling is more powerful. And the cooling is accomplished by compressing or forcing together, and the more the outer layers have been cooled in proportion to the inner, with the greater compressing force must the former work upon the latter, which by their resistance react upon the outer layers.

The compressing force is, however, by no means exclusively dependent on the rapidity of cooling, but also on the compactness of the material. For the smaller this is the more readily does the material allow itself to be compressed, and the less accordingly becomes the resistance which the interior develops against a certain compressing force, so that no great resistance is ever experienced in such a case. In this way is explained the fact, which has already been pointed out, that the effect of hardening is greater on the compact ingot-iron than on the weld-iron, which is looser in its structure. Further, the compressing force is naturally in a very high degree dependent on the limit of elasticity of the material, and the smaller this is the more easily are the outer layers stretched by the resistance of the inner, and the smaller, therefore, is the portion of the contracting force which can be made available as actually compressing. All substances which in iron increase its limit of elasticity ought, therefore, to have an influence on its power of hardening; a fact which has also been confirmed by experience, inasmuch as not only carbon, but also manganese, silicon, and phosphorus have shown themselves to have some influence in this respect. The action of the other substances, however, upon the degree of hardening is limited in comparison with that of carbon, and the explanation of this appears, as has already been pointed out, to lie mainly in the more intimate union between iron and carbon, which a violent compression produces. As the union between these substances becomes more intimate, the influence of the content of carbon on the iron also becomes greater, and it is, as we shall now see, just an increased exertion of the influence of the carbon on the iron that is attained by hardening.

The limit of elasticity and ultimate tensile strength of the unhardened iron increase, as we have long known, and as Table II. shows, with its content of combined carbon, not, however, to an unlimited extent, but in the graphite-free iron series (malleable iron and steel) to a content of carbon of about 1 per cent., higher in proportion as the steel is purer or consists more exclusively of iron and carbon, but on the other hand lower in proportion, as along with these it contains other substances which have an influence on its properties. Within the graphite bearing iron series, or pig iron, the limit of elasticity and the ultimate tensile strength increase together with the content of combined carbon, but to a somewhat higher limit, or a contents of carbon of about 1.5 per cent. The reason of this difference again clearly is, that the more combined carbon a pig iron smelted from a certain furnace charge contains, the less is in general its content of graphite, and the less accordingly is the weakening action which it produces by separating the molecules of iron. When the content of combined carbon exceeds figures which under various circumstances approximate more or less closely to these limits, the tensile strength diminishes.

If we now compare with this the influence of hardening as stated above, it immediately appears that it only still further increases the degree of the properties just mentioned as dependent on a certain content of combined carbon, quite as if the content of combined carbon had been increased by the hardening; and in the most complete correspondence with this stands the fact that the ultimate tensile strength is not continuously increased by the hardening; but if steel with a large content of carbon be strongly hardened, the limit of the increase of tensile strength is exceeded, as is clearly shown by Table II. The correspondence between the action of hardening and of a larger content of carbon is thus manifest in this case also. The diminution of the tensile strength by a too strong hardening of a highly carbonaceous steel is, however, much more rapid than the corresponding decrease in consequence of the content of carbon being too large in the unhardened steel (see the highly carbonaceous kinds of steel from Högbo and Wikmanshyttan in Table II.), but this difference is easily explicable by the great tension which a strong hardening must produce in the highly carbonaceous steel. When a hard steel is too strongly hardened, the larger pieces in particular readily break in pieces of themselves, which again is a natural consequence of the fact already mentioned, that the limit of elasticity in this case nearly coincides with the ultimate tensile strength, and therefore when the resistance of the inner layers against the contraction of the outer becomes so strong that the limit of elasticity is exceeded, fracture of the hard steel readily takes place instead of the extension which would have taken place in the outer layers of a less hard steel.

The same correspondence between the influence of hardening and an increased content of carbon also prevails in respect of ductility and hardness and the fineness of the grain. The first of these properties diminishes, and the two others increase, as we all know, with the content of carbon, and corresponding changes are produced, as we have seen, by hardening.

That the effects of hardening are produced by the compression caused by rapid cooling is further confirmed by the correspondence between them and the influence of cold working. For, as is well known, the limit of elasticity and the breaking strain and fineness of grain are increased by powerful mechanical treatment when the iron is in a cold or only slightly warm state, as, for instance, both by wire-drawing and rolling and hammering in a cold or slightly warm state, while the ductility on the other hand is diminished. In the same way the rolled iron commonly has a lower limit of elasticity and less ultimate tensile strength but greater ductility than the hammered, inasmuch as hammering in general is continued to a much lower temperature than is common at the close of rolling; but by sufficiently strong ignition all the changes produced by cold working can, as we know, be again taken away, and the same, as we have seen, is the case with the corresponding changes caused by hardening.

Another proof that the effects of hardening depend on the oft-mentioned compression is afforded by the behavior of burnt iron in hardening. Burnt iron, as is well known, is the name given to an iron which, through to long continued or strong heating, has had the opportunity of assuming a crystalline texture, with the brittleness which accompanies it on account of diminished cohesion of the crystals. The disposition to such a crystalline segregation is less in proportion as the iron is both more mixed with cinder and freer from certain substances; but the more carbon, and in particular the more phosphorus, it contains, the greater is the liability of the iron to be burned, and the more care ought, therefore, to be taken with the heating, if it is not, in consequence of this distribution into crystals, to fall in pieces utterly, or at least crack, as soon as the drawing begins. An iron practically free from these substances can, without danger of burning, be heated to the strongest welding heat, but with an increase of carbon in the iron all the more care, as has been already said, must be observed in the heating, and this is rendered necessary in a much higher degree by an increased content of phosphorus in the iron. So long as the content of carbon in the iron is quite small, however, this detrimental influence of phosphorus is still rather limited, more particularly if the iron contains at the same time a good deal of manganese; but the greater the content of carbon in the iron, the more is the detrimental influence of phosphorus increased, and the first requisite of a really good steel is, therefore, that it contains as good as no phosphorus.

An iron whose disposition to burn is so great that this detrimental change cannot in general be avoided, has from old times been called "old short," from the brittleness caused by its crystalline texture. But in this connection it must be kept in mind that the disposition to burn, increasing with the content of phosphorus, is not only counteracted by the presence of manganese and the absence of carbon, but also that the iron molecules in the puddled iron are intercalated with layers of a fine interspersed cinder, which is unfavorable to the formation of the coarse crystals which cause the brittleness. A certain content of phosphorus is, therefore, not so detrimental to the puddled iron, loose in its texture and mixed with cinder, as to the cinder-free ingot iron, and if by the adoption of a suitable treatment the production of even the least sign of crystalline texture be prevented, a content of phoshorus rising to two tenths per cent. does no great harm to the iron so long as it is in the non-crystalline condition just mentioned; but the difficulty is just to avoid the crystalline texture in the phosphoriferous iron, and, if success is attained in this, to prevent the formation of crystals in the case of a possible future reworking of the iron in a warm state.

Now, whether an iron, which from one cause or another has a tendency to burn, becomes after a certain heating, burned or not, depends mainly on the degree to which it is afterwards drawn out; for the more an iron, which when heated has begun to be crystalline, is afterwards drawn out in a warm state, the less is the danger that the crystalline texture will remain in the fully drawn iron. In this way it is explained why a greater degree of drawing out, and thus also larger ingots, are requisite for a more than for a less phosphoriferous iron. If however, an iron, after a certain heating, followed by drawing, still appears to be coarsely crystalline or burned, this burning can frequently be removed by heating the iron anew to a certain welding heat, properly adjusted to its contents of carbon and phosphorus, succeeded by a new drawing out; but we must not, however, make ourselves too sure that we can in this way always remove the burning or cold-shortness.

In complete correspondence with this, experience has shown that burning can be removed by a corresponding heating, followed by hardening instead of by drawing; and this circumstance affords a new proof of the correctness of the view, that the effects of hardening must depend on the compression caused by the contraction, as it, like the drawing out, can remove the crystalline texture. In close connection with this, doubtless, also stands the circumstance that has already been pointed out, that the hardening of an iron which contains much phosphorus, but little carbon can even increase its ductility, for the somewhat crystalline texture of a phosphoriferous iron may be destroyed by hardening, whereby again its ductility is greatly increased.

To the older observations which we have noticed above, there has lately been added a new experience, which further confirms the correctness of the view that the effects of hardening depend on the compression caused by the contraction. The experience now referred to, viz., that ingot metal free from blowholes can, without drawing, and merely by hardening, followed by a new heating to redness, become quite equal to ingot metal that has been drawn out, is indeed not so altogether new, for it was communicated eleven years ago to the Technical Society of St. Petersburg, by Herr Chernoff, who, however, sought to explain it in a way that did not appear satisfactory to me. It is, however, first through the splendid efforts made at Terrenoire to produce castings of Martin metal equal in quality to drawn ingot metal that the fact in question has become more generally known and has attracted due attention.

Table VI. shows to how great an extent not only the limit of elasticity and ultimate tensile strength, but also the ductility of ingot metal, are increased by its being drawn out while warm; but if we compare with it the results from Terrenoire, given in Tables III. to V., we see that improvements quite as great can also be attained without drawing, merely by proper heating followed by hardening and a renewed heating in order to increase the ductility. The explanation of this appears to me evidently to be that the contraction from without inwards, caused by the cooling in this as in the cases formerly described, brings about a compression similar to that caused by drawing with the effects which follow it; but it is a fact that in proportion as the content of carbon is greater, the ductility, when this method is employed, is less than in drawn metal with the same content of carbon, for the undrawn ingot metal becomes, by hardening alone, almost the same as that which is hardened after being drawn. If the hardening, however, be followed by a new heating to redness, not only the brittleness but also the excess in the limit of elasticity may be taken away, so that only so much remains as would have been produced by drawing alone, and the undrawn casting is now comparable with ingot metal of the same composition, which has been drawn, but not hardened.

It is, at least if the content of manganese be not all the greater, however, only when the percentage of carbon exceeds 0.3 that the ductility suffers through hardening any loss endangering the strength of the material, and it therefore appears probable that in all the cases where special ductility is not demanded, it may not be necessary to reheat to redness castings poor in carbon after they have been hardened. The higher the temperature at which the reheating takes place, provided, however, it does not exceed a full red heat, the more is the ductility increased, while on the other hand the limit of elasticity and the ultimate tensile strength are thereby diminished, until they descend to nearly the same minima which characterize ingot iron or ingot steel of the same composition, which have been heated to redness after hardening. By modifying this reheating on the other hand, it is possible to bring the hardened castings to intermediate stages of these qualities, quite as is the case, as we have seen, with the hardened drawn iron or steel. All becomes clear and easily understood if we only consider that the figures given in Table III. (*vide* page 504 *ante*) for the hardened and reheated castings ought not to be compared with the figures in the same column for the hardened, but with those for the unhardened and drawn sorts of iron and steel. The small differences in the properties of the specimens corresponding with each other, in degrees of hardness which still remain, are by no means greater than those which occur in the case of comparisons made exclusively between drawn sorts of iron and steel, and they may easily be explained by different degrees of reheating after the hardening.

It may be stated as an objection to the correctness of the explanation of these important facts now proposed that the properties of Martin castings may be improved, as Tables IV. and V. show, merely by heating to redness without the help of proper hardening. It must be admitted that it is possible, when skill and practice have been acquired, to attain merely by heating to redness followed by slow cooling of the drawn iron or steel a diminution in the limit of elasticity and ultimate tensile strength; and as the same thing can also happen, as Table VI. shows, with undrawn ingots, it appears very strange at the first glance that these properties can also be increased in the undrawn ingot metal merely by heating to redness. It was also just the circumstance that in the accounts of the Terrenoire process, with the exception of the addition of manganese-silicon-iron, the heating to redness was almost exclusively dwelt upon, and it was stated that merely with its help it was possible to make undrawn compact ingot metal equal to that which had been drawn that made me doubtful of the whole thing, until I had an opportunity of studying it more thoroughly at the Paris Exhibition.

An examination of Tables IV. and V., however, shows, without going further, that if the limit of elasticity and breaking strain of the castings be somewhat increased merely by heating to redness, this increase is by no means so great as that attained by hardening the same pieces. In fact, it also stands in complete correspondence with the views expressed above as to the causes of hardening that an undrawn ingot metal ought to have, its limit of elasticity and ultimate tensile strength somewhat increased merely by sufficiently strong heating, for though cooling takes place comparatively very slowly, it is, however, provided it goes on from without inwards, always attended with a compression caused by contraction; but so long as this compressing force, in consequence of the slow cooling, is weaker than that attained by common drawing, are the alteration of the texture of the material and the increase of the limit of elasticity less than when caused by drawing.

The consequence of this must be that a drawn iron or steel—above all, when the drawing, as in the case of hammering, has been continued to a low temperature—loses in limit of elasticity and ultimate tensile strength by heating to redness followed by slow cooling, while an undrawn ingot may increase to some extent in these properties, although in a smaller proportion, according as the degree of heating was less and the cooling slower. On the other hand, by sufficiently rapid cooling or actual hardening, the oft-mentioned properties are increased in the material to a higher degree than can be attained merely by drawing; but by renewed heating this excess can be again removed.

That the ductility of the undrawn ingot metal has increased by heating and slow cooling, as Tables IV. and V. show, still more than by a rapid cooling, stands in full correspondence with the common effects of heating, and therefore require no further notice; but on the other hand, it remains to endeavor to explain how it could be possible that the experiments with unannealed and annealed ingots, the results of which are given in Table VI., should show results of heating so different from those just stated, that it even produced in them a slight diminution in the limit of elasticity and ultimate tensile strength. One cannot of course give any decided utterance on this point without being himself present at the experiments, and in the absence of detailed statements of the degree of heating and the manner of cooling, but it appears to me to be probable that the cause of this difference is to be sought for in the degree of heating having been considerably lower in this case, for if it had been sufficiently low, it is not to be expected that the cooling following upon it would have been able to exercise any noteworthy influence on the limit of elasticity and ultimate tensile strength of the ingot, especially if the cooling had been very slow. A deficiency of compactness in these ingots may also possibly have conduced thereto; but that their heating was actually comparatively trifling appears to be confirmed by the consequent increase of the percentage of elongation being so small.

Another remark which also may be urged against the conception of the influence of the manner of cooling here expressed is, that if these changes be caused by the compression produced by contraction, the same ought also to take place at the first cooling of the ingot, the rather because this proceeds from a still higher temperature. But the difference is quite manifest. In the latter case we have a fused mass which, through the cooling of the walls of the mould, begins to solidify at them. No compression of the material still in a fluid state in the interior can, however, come in question, for it is thus pressed only upwards; and when the whole mass is solidified, we have here already from the beginning such a difference between the temperature of the outer and inner layers that the material never comes to be exposed to nearly so severe a pressure as when we with like rapidity cool a solid body, which, when the cooling begins, is apt to be warmer in the outer than in the inner layers.

Although the pressure must thus be very much less in the forming of ingots than in cooling after a renewed heating, it is, however, without question very noticeable in the former case, which is best seen both by the behavior of pig iron, which becomes whiter when rapidly cooled in metal moulds than when run out into sand or clay moulds, and by steel castings being less coarse in the grain when cast in metal moulds than when cast in others; but the contraction which takes place in the formation of ingots is at all events not sufficient to bring about in the metal such an alteration as is caused by drawing.

THE EMPLOYMENT OF THE TERRENOIRE PROCESS

Terrenoire at the time of the Paris Exhibition had not been able to get into proper order its large oil basin and crane intended for the hardening of large pieces, and the greater portion beyond comparison of the large pieces of compact Martin casting which Terrenoire exhibited were therefore not yet finished, but to be looked upon as in process of manufacture. This, on the other hand, did not hold good of the armor-piercing projectiles, which have already, for a number of years, been made on a great scale of Martin steel merely by casting in metal moulds, followed by hardening and tempering. The moulds employed for this purpose consisted of two pieces standing one above the other, of which the under formed the point of the projectile and the upper its cylindrical part, but upon the latter there was besides a half meter high contracted sunkhead in dry sand. These projectiles are cast of steel with 0.45–0.6 per cent. carbon, 0.25–0.3 per cent. silicon, and 0.5-0.6 per cent. manganese. The hollow projectiles, too, are cast massive and afterwards bored out, but besides they are subjected to no other operation than hardening, followed by tempering. The hardening proceeds by dipping the pointed part, after the whole projectile has been heated to a red heat, first into water until the redness has disappeared from its surface, after which the whole piece is sunk in an oil-bath, where it is allowed to lie until it is quite cool. Then follows a gentle heating for tempering, or only so strong that the adhering oil is removed. The oil-bath intended for the hardening, it was considered, ought to be at least so large that the weight of oil was four times greater than that of the piece that was to be hardened.

Very satisfactory experiments had indeed been made at the time of the Exhibition with some small cannon tubes made of compact Martin castings, but it was first during winter that the Terrenoire process may be said rightly to have got its baptism of fire; for according to a communication which M. Pourcel has kindly sent me quite lately, two armor plates cast of their compact Martin iron have been tested at Gavre with great success. One of these plates, both of which were 350 mm. thick, contained 0.239 per cent. carbon, 0.15 per cent. silicon, and quite a small quantity of manganese. This armor plate was hardened in oil and reheated afterwards. The other somewhat harder plate, with 0.314 per cent. carbon, was only heated to redness. These were tested with a 320 mm. cannon in quite the same way as several hammered and rolled armor plates of the same dimensions from Creusot, partly at right angles to the plates with pointed projectiles of hardened cast iron, and partly obliquely to the plates with projectiles cast at Terrenoire of compact Martin steel and hardened. In the former case the charge of powder was 53 kilogrammes, and the speed of the projectile 370.6–371.7 meters, and in the latter the charge of powder was 63 kilogrammes, and the speed of the projectile 414.8–432.2 meters per second. Neither of these two plates was penetrated by a shot, though cracks of course arose. Yet the unhammered and unrolled armor plates of Terrenoire have stood the test better than the hammered and rolled plate from Creusot. Notwithstanding the lesser content of carbon in the hardened plates, the projectiles did not penetrate so deeply into them as into those that were only heated to redness

(318 mm. against 350 mm. for the perpendicular shots, and 204 mm. against 234 mm. for the oblique), while the former, so far as can be judged from the drawings received, were at least not worse cracked than the latter.

Both many and great are the advantages which we appear to be justified in expecting from this process, for it renders it possible in many cases to replace with an oil basin and a crane the enormous steam hammers which are otherwise necessary for the production of large forgings of ingot metal, and which are so costly that only comparatively few works can procure them. Great care is indeed required, not only at the Martin furnaces themselves, in order to obtain from them materials which are at the same time compact and of the proper degree of hardness or the requisite composition, but also at the succeeding heatings; but without great care no success is in fact attained in the hammering of ingot metal in the long run, and the danger of burning must in such a case be greater, for even if the hammer be heavy enough to make its influence properly felt to the very core of the metal, which is often not the case, the forging of large pieces is done at many heats, and in such cases such parts as lie nearest to those that for the time are under the hammer may easily be burned to a greater or less extent, for they have been strongly heated without being again hammered.

THE ADVANTAGE OF THE HARDENING OF DRAWN INGOT IRON.

Besides the extensive employment which ought to be expected in the way now pointed out for the hardening of undrawn ingot metal, it appears also as if we might reckon on the hardening of hammered or rolled articles of iron being more generally used than has hitherto been the case, and yet the great increase of strength and toughness which hardening produces in pretty compact iron that has been refined in the open hearth has been known so long that even Sefström refers to it. Still more striking, as we have seen, is the increase thereby attained in the strength of the compact ingot iron, and at some works, both Swedish and foreign, it has been turned to account more particularly in the making of rings for cannon; but the use of hardening in similar cases is far from being so general as it deserves to be. It is already common at many works to subject the pieces as soon as they are finished to a uniform heating to a red heat, in order to remove the tension which unequal or partial heating and working often produce in articles of ingot iron, but only perhaps in the cases in which the content of carbon exceeds 0.3 per cent., or in which the principal stress is laid upon the attainment of the greatest possible ductility, ought the pieces afterwards to be cooled slowly. In proportion as more importance is attached to a high limit of elasticity and breaking strain, it appears on the other hand desirable that the heated finished pieces ought to be hardened.

In his valuable paper, "Remarks on the Manufacture of Steel, and the Mode of Working it," Chernoff sets forth, with very warm approval, the great advantages of always hardening articles of ingot iron, and he there points out also how it is possible merely by hardening to remove the coarse crystalline texture, and the consequent brittleness, which distinguish iron which has been long exposed to slight concussions. This alteration, as is well known, is specially prevalent in wagon axles, and it has accordingly given occasion to the precautionary measure that all wagon axles, even if they are to outward appearance never so faultless, are rejected, or at least subjected to special examination, after running a certain number of miles. The advantage of getting these axles made again serviceable merely by hardening is manifest, and the possibility of doing so appears accordingly to be deserving of thorough investigation.

[The tables referred to in this Article are for convenience all placed together on the following pages.]

TABLE I.—AVERAGES OF BREAKING TESTS OF INGOT IRON PLATES CARRIED OUT BY C. A. DELLVIK AT THE SWEDISH IRON BOARD'S TESTING INSTITUTE, ON STRIPS OF 70 BY 9 MILLIMETERS' SECTION AND 200 MILLIMETERS IN LENGTH.

Average	The Plates' Contents of					Unheated.					Heated to Redness.					Hardened in Water.				
	Carbon per cent.	Silicon per cent.	Phosphorus per cent.	Sulphur per cent.	Manganese per cent.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 200 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 200 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 200 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.
Of ten tests of plates from five different Bessemer ingots from Motala (Bangbro)....	0.1 to 0 3	0.017 to 0.029	0.028 to 0.031	trace to 0.01	0.151 to 0.267	21.5	42.6	26.9	50.1	0.506	18.4	38.2	31.6	54.7	0.482	24.3	63.5	15.7	33.3	0.383
Of ten tests of plates from five different Bessemer ingots from Iggesund...........	0.1 to 0.3	0.016 to 0.037	0.016 to 0.024	0.02 to 0.025	0.094 to 0.360	22.3	43.8	27.4	50.9	0.512	19.8	41.7	29.9	53.3	0.475	26.0	64.8	14.8	33.3	0.403
Of ten tests of plates from five different Bessemer ingots from Uddeholm......	0.05 to 0.18	0.006 to 0.018	0.020 to 0.028	0. to trace	0.050 to 0.122	18.5	37.7	30.6	57.0	0.491	17.7	37.0	32.2	58.3	0.478	26.7	65.1	14.3	38.1	0.411
Of all the Bessemer plates.....	..	..	..	..	..	20.8	41.4	28.3	52.7	0.502	18.6	39.0	31.2	55.4	0.477	25.7	64.5	14.9	34.9	0.398
Of two tests of plates from different Martin ingots from Uddeholm................	0.14 to 0.23	0.021 to 0.042	0.011 to 0.015	0.	0.086 to 0.101	13.1	36.0	36.7	57.4	0.364	14.3	34.8	33.0	61.2	0.411	19.4	53.4	18.0	42.7	0.363
Of two tests of plates from different Martin ingots from Motala..................	0.17 to 0.22	0.018. to 0.028	0.030 to 0.034	0. to trace	0 137 to 0.273	19.1	41.0	29.7	49.2	0.466	18.7	38.8	32.4	56.7	0.482	22.7	55.1	19.3	47.8	0.412
Of all the Martin plates........	..	..	..	..	..	16.1	38.5	33.2	53.3	0.418	16.5	36 8	32.7	58.9	0.448	21.1	54.3	18.7	45.3	0.389

TABLE II.—TESTS OF THE TENSILE STRENGTH OF PUDDLED IRON, BOTH UNHARDENED AND HARDENED, IN DIFFERENT WAYS, OF IRON REFINED IN THE OPEN HEARTH, AND OF INGOT METAL.

Maker.	Variety of Iron and Steel.	Mode of Treatment of Test Bar.	Test Bar's Contents of Carbon per cent.	Test Bar's Contents of Phosphorus per cent.	Breaking Load. Kilog. per sq. mm.	Elongation per cent.	Contraction % of original Sectional Area.	Examination carried out by.	Average.
Surahammar	Puddled iron, rolled	Unheated	0.20	?	34.0	19.07*	?	S‡	five tests
"	" "	Heated to redness, slowly cooled in hot small charcoal	....	..	32.9	?	63.7	"	
"	" "	" hardened in water	....	..	48.5	6.2	33.9	"	two tests
Bowling	" "	Strongly heated and hardened in coal tar	?	?	44.2	22.4	40.5	K§	three tests
"	" "	" " oil	?	?	45.4	18.8	33.6	"	two tests
"	" "	" " water	?	?	51.6	19.6	34.9	"	
	Puddled iron, piece of crank-axle, sample taken in the direction of the length of the axle	Unheated	?	?	31.2	20.6	24.3	"	
	" " " "	Hardened in water	....	..	37.5	16 6	19.0	"	
	Puddled iron, piece of an armor plate, sample taken across	Unheated	?	?	24.3	4.8	5.9	"	
	" " " "	Hardened in water	...	..	25.4	3.0	4.0	"	
Lesjöfors	Hearth-refined iron, rolled	Unheated	0.06-0.08	0.02	32.9	21.2†	70.2	S‡	two tests
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	31.5	24.0*	66.2	"	two tests
"	" " "	" hardened in water	....	..	44.3	8.0*	63.8	"	three tests
Halsthammar	" " "	Unheated	0.07	?	35.8	16.7†	56	"	
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	33.4	?	74	"	
"	" " "	" hardened in water	....	..	35.6	?	58	"	
Aryd	" " "	Unheated	0.07	0.26	42.1	7.1†	15.4	"	five tests
"	" " "	Heated to redness and hardened in water	....	..	47.1	17.5*	27.9	"	three tests
Högbo	Bessemer Iron, hammered	Unheated	0.33	0.02	50.2	6.0†	62.4	"	two tests
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	36.0	19.0*	72.8	"	
"	" " "	" hardened in water	....	..	56.2	13.0*	57.6	"	
"	Bessemer Steel, hammered	Unheated	0.68	0.02	71.2	3.7†	34.8	"	
"	" " "	Heated to redness and hardened in water, then heated to 250 deg. C. for half an hour	....	..	72.5	1.6*	20.5	"	two tests

"	" " "	Unheated	1.05	0.02	72.4	3.4‡	43.9	"	two tests
"	" " "	Heated to redness and hardened in oil	....	..	101.7	0.0*	0	"	
"	" " "	" " water	....	..	28.9	0.0*	0	"	
"	" " "	Unheated	1.14	0.02	89.0	2.9‡	40.7	"	two tests
"	" " "	"	1.35	0.02	74.6	2.4‡	14.6	"	two tests
Wik-manshyttan	Uchatius steel, rolled	"	0.69	0.01	72 8	11.3‡	37.7	"	
	" " "	Heated to redness and hardened in water, then heated to 250 deg. C. for half an hour	....	..	76.6	3.0*	44.9	"	
"	" " "	Heated to redness and hardened in oil	....	..	96.1	2.0*	0.4	"	
"	" " "	Unheated	0.78	0 01	83.4	10.8‡	28.0	"	
"	" " "	Heated to redness, cooled slowly in hot small charcoal	....	..	68.1	?	36.0	"	
"	" " "	" hardened in water, then heated to 250 deg. C. for half an hour	....	..	63.2	0*	0	"	
"	" " "	Heated to redness and hardend in oil	....	..	118.4	?	9.9	"	
"	" " "	Unheated	1.16	0.01	98.3	4.6‡	12.4	"	
"	" " "	Heated to brownness and hardened in water, then heated to 250 deg. C. for half an hour	....	..	92.5	6.0*	23.0	"	
"	" " "	" " " " " " "	....	..	100.6	?	13.0	"	
"	" " "	Heated to full redness and hardened in oil	....	..	38.6	0*	0	"	
"	" " "	Unheated	1.22	0.01	101.7	4.5‡	4.8	"	
"	" " "	Heated to redness, slowly cooled in hot small charcoal	....	..	65.5	?	45.0	"	
"	" " "	" hardened in oil	....	..	137.0	1.1*	26.0	"	
"	" " "	Heated to full redness, and hardened in oil	....	..	71.2	0*	0	"	
"	" " "	Unheated	1.56	0.01	85.3	2.5†	2.0	"	
Krupp, Essen	Crucible Steel, hammered	"	0.62	0.02	60.1	6.4‡	54.0	"	
"	" " "	Heated to redness and hardened in oil	....	..	108.0	?	2.5	"	two tests
"	" " "	" " " water, then heated to 250 deg. C. for half an hour	....	..	85.9	0*	7.0	"	
Jowitt, Sheff'ld	Crucible steel, "chisel steel"	Strongly heated and slowly cooled in ashes	?	?	85.6	12.9	7.0	K§	
"	" " "	" " hardened in oil	....	..	151.4	3.5	3.3	"	
"	" " "	" " " water	....	..	63.3	0	0	"	
"	" " "	" " " " tempered to yellow	....	..	71.0	0	0	"	
"	" " "	" " " " " spring blue	....	..	73.7	0	0.7	"	
"	" " "	" " " " " fall blue	....	..	78.8	0	0.7	"	
"	" " "	Moderately heated, and slowly cooled	....	..	83.8	9.4	7.7	"	
"	" " "	" hardened in coal tar	....	..	117.4	6.4	6.0	"	
"	" " "	" " oil	....	..	130.1	3.5	2.7	"	
"	" " "	Slightly heated, and slowly cooled	....	..	88.6	16.5	10.0	"	
"	" " "	" hardened in coal tar	....	..	99.8	13.1	8.7	"	
"	" " "	" " oil	....	..	114.7	6.8	5.0	"	

* The elongation near the place of fracture is not included in this. † The elongation calculated on a length of 5 feet. S—Styffe and K—Kirkaldy.

‡ Jernkontorets Annaler, 1866. § Results of an experimental inquiry into the tensile strength of wrought iron and steel.

Table III.—Breaking Tests of Martin Metal carried out at Terrenoire on Round Rods 20 Millimeters in Diameter and 200 Millimeters in Length.

	The Rods' Contents of					Unhardened.					Hardened in Oil.					Hardened in Water.				
	Carbon per cent.	Silicon per cent.	Phosphorus per cent.	Sulphur per cent.	Manganese per cent.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation on a Length of 200 Millimeters.	Contraction per cent. of original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation on a Length of 200 Millimeters.	Contraction per cent. of original Sectional Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity in Kilogrammes per Square Millimeters.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation on a Length of 200 Millimeters.	Contraction per cent. of original Sectional Area.	Ratio of Elastic to Breaking Weight.
Common Martin Metal, drawn..............	0.15	trace	0.035	trace	0.213	18.2	36.4	32.3	65.7	0.500	31.4	46.8	23.7	66.1	0.671	33.1	50.4	18.25	71.2	0.657
" " "	0.49	"	0.070	"	0.200	23.0	48.0	24 8	40.3	0.479	46.4	71.0	12.5	26.8	0.653	49.3	78.2	7.0	35 6	0.630
" " "	0.709	"	0.062	"	0.266	30.8	68.2	10.0	8.5	0.452	67 8	97.0	1 25	3.3	0.699	Broke in pieces in hardening.				
" " "	0.875	"	0.055	"	0.250	32.8	73.2	8.4	6.8	0.448	77.8	104 6	0.8	2.0	0.745	"	"	"		
" " "	1.050	"	0.063	"	0.255	39.5	86.0	5.2	4.5	0.459	92.6	130.8	1.0	2.0	0.708	"	"	"		
" " "	0.450	"	0.067	"	0.521	26.3	51.8	24.5	47.0	0.508	41.7	76.5	12.0	40.7	0.545					
" " "	0.467	"	0.072	"	1.060	31.2	61.1	21.4	47.3	0.511	65.0	99.0	?	?	0.657					
" " "	0.515	"	0.061	"	1.305	41.2	76.5	17.4	45.7	0.539	Broke in pieces in hardening.									
" " "	0.560	"	0.058	"	2.008	47.7	88.5	10.5	32.7	0.539		"	"	"						
" " "	0.310	"	0.247	"	0.746	33 4	55.2	23.5	47.8	0.605	41.2	71.5	13.0	45.0	0.576					
" " "	0.274	"	0.273	"	0.800	36.2	56.2	24.0	57.1	0.644	42.0	76.5	13.3	43 3	0 549					
										0.633					0.552					
" " "	0.310	"	0.398	"	0.693	37.8	59.7	25.25	53.6	0.627	44.2	80.0	?	22.9	0.559					
											Hardened in oil, then re-heated									
Martin Castings: free from blow-holes undrawn...	0.287	0.233	0.076	"	0.693	20 7	45.7	8.8	2.6	0.453	28.8	49.3	21.4	36.4	0.584					
" " "	0.459	0.221	0.078	"	0.670	25.2	52.2	3.5	1.5	0.483	30.3	56.0	16.9	23.4	0.541					
" " "	0 750	0.163	0.097	"	0.672	34.7	62.3	3.1	4.9	0.557	36.3	72.3	9.4	10.9	0.502					
" " "	0.875	0.322	0.085	"	0.772	37.8	60.5	1.4	?	0.625	47.8	82.4	3.0	3.1	0.580					

Table IV.—Tests of the Tensile Strength of Martin Castings Free from Blowholes, carried out at Terrenoire.

	The Metals' Contents of			Unworked Castings.			Castings Heated to Redness.			Hardened and Slightly Re-heated.		
	Carbon per cent.	Silicon per cent.	Manganese per cent.	Limit of Elasticity Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity, Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Ratio of Elastic to Breaking Weight.	Limit of Elasticity, Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Ratio of Elastic to Breaking Weight.
Soft metal.......... }	0.26	0.26	0.41 {	17.2	47.8	0.360	19.2	46.5	0.413	31.1	55.0	0.565
" .... }				19.3	46.8	0.412	23.5	49.2	0.477	31.3	56.5	0.554
"	0.317	0.30	0.48	18.1	56.8	0.319	20.2	54 2	0.373	35.5	67.7	0.524
Averages..	...	...	...	18.2	50.5	0.360	21.0	50.0	0.420	32.6	59.7	0.546
Moderately hard metal. }	0.425	0.275	0.75 {	31.2	62.5	0.499	36.9	72.9	0.506	39.0	76.8	0.508
" " }				33.0	57.9	0.570	34.8	74.8	0.465	36.6	75.2	0.486
" "	0.45	0.35	1.10	30.8	59.8	0.515	34.0	74.0	0.460	45.0	85.0	0.530
Averages..	...	...	...	31.7	60.1	0.527	35.2	73.9	0.476	40.2	79.0	0.509
Hard metal............	0.55	0.405	1.05	25.3	58.0	0.436	25.3	73.0	0.347	28.8	77.2	0.374
" .... }	0.635	0.55	0.95 {	23.7	56.0	0.423	29.4	73.0	0.403	42.9	111.5	0.385
" .... }				31.9	52.2	0.611	36.5	78·5	0.465	55.0	116.0	0.474
Averages..	...	...	...	27.0	55.4	0.487	30.4	74.8	0.406	42.2	101.6	0.415

Table V.—Tests of Tensile Strength carried out at Terrenoire on Round Rods 14 Millimeters in Diameter and 100 Millimeters in Length of Martin Castings Free from Blowholes.

	The Metals' Contents of			Unheated Castings.				Heated to Cherry-Red and Hardened in Oil.*			
	Carbon per cent.	Silicon per cent.	Manganese per cent.	Limit of Elasticity Kilos. per Sq. Mm.	Breaking Load in Kilos. per Sq. Mm. of original Area.	Contraction per cent. of original Area.	Ratio of Elasticity to Breaking Weight.	Limit of Elasticity Kilos. per Sq. Mm.	Breaking Load in Killos. per Sq. Mm. of original Area.	Contraction per cent. of original Area.	Ratio of Elasticity to Breaking Weight.
Soft Metal.................	..	0.203	0.42	23.2	49.2	45.0	0.475	38.2	62.1	35.0	0.615
"	..	0.209	0.63	23.8	50.3	?	0.473	31.5	55.1	?	0.572
"	..	0.233	0.61	20.0	45.7	?	0.438	29.6	60.0	?	0.493
"	..	0.263	0.66	26.8	51.0	43.5	0.525	?	?	?	?
Averages	0.2	0.227	0.58	23.4	49.0	..	0.478	33.1	59.1	..	0.560
Hard Metal for projectiles....	..	..	..	33.9	70.0	?	0.484	42.0	75.2	?	0.559
" "	..	..	..	33.5	76.2	?	0.440	47.1	83.0	?	0.567
" "	..	..	..	34.0	75.5	?	0.450	46.8	84.0	?	0 493
" "	..	..	..	36.0	78 0	?	0.462	41.0	79.8	?	0.514
" "	..	..	..	36.0	79.5	?	0.453	44.0	80.0	?	0.550
" "	..	..	..	36.2	76.2	?	0.475	47.8	90 0	?	0.531
" "	..	..	..	36.5	80.0	?	0.456	46.1	88.8	?	0 519
Averages............	0.5	0.39	0.88	35.2	76.5	..	0.460	45.0	83.0	..	0.542

* The hardening of the hard metal has probably been followed by some re-heating, although this is not stated by Mr. Holley, who first published both this and Table IV.

TABLE VI.—TEST OF THE TENSILE STRENGTH OF BESSEMER METAL FROM WESTANFORS, FAGERSTA, CARRIED OUT BY MR. KIRKALDY ON ROUND RODS, 34 TO 43 MILLIMETERS IN DIAMETER, AND 244 MILLIMETERS IN LENGTH.

	UNDRAWN INGOTS.											
	UNANNEALED RODS.						ANNEALED RODS.					
Per-centage of Carbon in Metal.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes, per Square Millimeter of original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.
0.2	15.6	37.2	11.6	11.9	0.479	42.2	14.2	37.1	18.2	27.1	0.383	50.9
0.4	19.9	38.8	3.4	4.2	0.513	40.5	18.4	37.3	4.2	5.2	0.493	39.3
0.6	27.3	46.8	1.7	2.3	0.583	46·9	26.6	45.0	2.2	2.3	0.590	46.1
0.8	33.5	47.2	1.1	1.5	0.710	47.9	27.3	44.7	1.7	2.1	0.611	45.7

HAMMERED DOWN FROM INGOTS WITH 152.4 MILLIMETERS SIDE TO 50.8 MILLIMETERS SIDE.

UNANNEALED RODS.						ANNEALED RODS.					
Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.	Limit of Elasticity in Kilogrammes per Square Millimeter.	Breaking Load in Kilogrammes per Square Millimeter of the original Sectional Area.	Elongation per cent. on a Length of 254 Millimeters.	Contraction per cent. of the original Sectional Area.	Ratio of Elastic to Breaking Weight.	Breaking Load in Kilogrammes per Square Millimeter of the Area of Fracture.
24.7	42.1	22.5	61.3	0.587	108.8	23.3	39.6	22.2	64.1	0.587	110.3
27.6	52.7	17.9	52.5	0.523	110.9	25.7	49.8	19.1	57.6	0.516	117.5
33.5	68.8	10.2	28.4	0.487	96.1	32.6	64.6	12.7	46.0	0 504	119.6
46.8	69.3	2.2	3.2	0.674	71.6	33.4	60.5	5.5	8.1	0.552	65.8

THE FRACTURE OF CAST IRON:

VISCOSITY AND RELEGATION IN METALS.

From "Papers of Civil and Mechanical Engineers' Society.

If (said the author) we break a piece of pig iron, and examine the fractured surface, we find that it is made up of a number of small facets. These facets have, while the surface is fresh, a very high degree of polish, and they give to the surface an appearance very much resembling that which is presented by the fractured surface of wrought iron when it breaks by cleavage. A microscopical examination of the facets, however, will show that they differ very considerably from the facets of wrought iron. In the first place, every element of the surface in a cleavage fracture of wrought iron is a plane, but the facets in the broken surface of pig iron are curved. Secondly, the facets in wrought iron show the metal itself; but in pig iron the metal is covered with a thin film of graphite. It is curious to observe that, break the pig iron where you will, it always shows this film of graphite; and in some fractures little bits of the metal may be seen hanging loosely to the surface. These bits may be removed with a penknife, or sometimes with the finger-nail; and on examination they are found to be completely surrounded with graphite. It would thus appear that the pig is built up with small particles of iron cemented together with graphite, somewhat after the manner in which a mass of masonry is built up with stones and mortar, and that the strength of the pig is not the strength of the iron, but of the graphite cement. This graphite is the uncombined carbon of cast iron. It becomes more and more combined with the iron every time the metal is re-melted. Re-melting makes the metal harder and stronger; but the strength very soon reaches a limit beyond which re-melting makes the metal weaker; and the hardness goes on increasing until all the carbon is combined, when the metal is very hard and very brittle, and is known as white iron.

The facets of pig iron vary in size according to the quality of the pig. When pig iron has been re-melted and re-cast, the fractured surface of the casting is greatly altered in general appearance. An increase of microscopic power will, however, show that the facets are still there, retaining their curved shape, although they are very much diminished in size. As well as being smaller, they look towards a greater number of directions in a casting than in pig, and give the peculiar roughness to the fractured surface of the casting. They are smaller near the sides than near the middle of a casting; and they constitute what is called the grain of cast iron, their size determining whether the metal is open and coarse grained, or close and fine grained. Besides the roughness due to the size and arrangement of the facets, the surface of fracture possesses a general form which is not dependent upon the facets. If we imagine all the little projections on this rough surface to be filed off, and the metal thus removed to be used in filling up the little depressions, we shall have a mean surface, the form of which is not constant. I had observed, whilst breaking cast-iron bars transversely, that this general form of the fractured surface was sometimes flat and at other times curved; and as neither the one form nor the other appeared to be due to any flaw or unsoundness in the bar, I felt curious to know what determined the form. To gratify this curiosity I have made observations on a number of bars; and without pretending to have discovered why fracture takes place in the way it does, I have arrived at a few results which may be interesting.

The bars upon which the observations were made were square in section, being 1 inch deep by 1 inch wide, and 3 ft. 4 inches long. Each bar was supported upon two knife-edge bearings, 3 ft. apart, and a weight was lowered steadily upon it midway between the bearings. Three lines were drawn upon each bar, one over each bearing, and one in the middle under the load. When a bar broke the distance between the center line and the fracture was measured, and it was noted whether the form of the fracture was curved or straight; if curved, the direction of the curve was also noted. Very soon it was found that the curves were all in one direction, except when interfered with by a flaw in the bar, and as the curvature was sometimes very slight, the following method was adopted for discriminating between straight and curved fractures:—The broken bar was looked at sideways, so as to show the vertical edge of the fractured surface, which would thus appear as a line; then, if it were possible to say from a mere inspection of this line which piece of the bar contained the center line, the fracture was classed as curved, if not, it was called straight. This method was, of course, used only for those fractures which were very nearly straight; but there were a great many so much curved as not to cause the slightest hesitation. By observing and recording in this manner, it was found that a great many more bars broke out of the center than in the center; and that those which broke in or near the center showed a fracture that was straight and at right angles to the upper and under surfaces of the bar; but those which broke at a distance from the center had, in a great many instances, a curved fracture of the following shape:—Starting as a perpendicular from the under-edge of the bar, the curve would bend very slightly towards the load, and would not deviate much from the perpendicular until it reached a position a little more than half way from the under to the upper edge, when it would begin to bend more sharply, increasing its curvature as it approached the upper edge of the bar, to which it would tend to set itself parallel. The curvature was usually greatest in those fractures which were furthest from the center of the bar; and the curve was always concave towards the center and downwards. . . . Even a large number of 1 inch bars would not show so great a difference as would a number of bars 2 inches deep; for in 2 inch bars the lower end of a fracture will, in some cases, be more than 1 inch farther than the upper end from the center of the bar. A fracture which is not very uncommon in 2 inch bars is of the following shape:—Beginning at the under edge, some 4 inches or 5 inches from the middle, it will travel part of the way across nearly perpendicular to the length of the bar; it will gradually increase its curvature until it becomes very sharply curved; it will then gradually flatten its curve and travel along near the upper edge until it reaches a point 1 inch or $1\frac{1}{2}$ inches near the middle of the bar, when it will suddenly turn a right angle, and come out at the top, giving a rounded corner to one piece, and to the other a long taper lip with a square end about $\frac{1}{8}$th inch thick. A fracture of this shape bears a rough resemblance to a hyperbola, having one asymptote along the upper edge of the bar, and the other perpendicular to it. But we have no 2-inch bars in this series. The following table shows the number of 1-inch bars upon which observations have been made. The first column gives the number of bars broken; the second gives the number of bars which broke with a straight fracture; the third, the number which broke with a curved fracture; and the fourth gives the distance between the fracture and the center line, as measured along the under side of the bar:

Number of bars broken.	Fracture straight.	Fracture curved.	Distance from center.	Number of bars broken.	Fracture straight.	Fracture curved.	Distance from center.
			Inches.				Inches.
28	28	0	0	2	0	2	2⅜
35	29	6	⅛	4	0	4	2½
41	26	15	¼	2	0	2	2⅝
37	20	17	⅜	2	0	2	2¾
24	8	16	½	1	0	1	3
30	19	11	⅝	1	0	1	3⅛
35	11	24	¾	1	0	1	3¼
24	4	20	⅞	1	0	1	3⅜
22	0	22	1	1	0	1	3½
15	3	12	1⅛	3	0	3	3⅝
20	0	20	1¼	2	0	2	3¾
11	0	11	1⅜	1	0	1	3⅞
14	2	12	1½	1	0	1	4⅛
11	1	10	1⅝	1	0	1	4¼
9	0	9	1¾	1	0	1	4⅜
3	0	3	1⅞	1	0	1	4¾
5	0	5	2	1	0	1	4⅞
1	0	1	2⅛	1	0	1	5
3	0	3	2¼	1	0	1	5⅛
			Total....	396	151	245	—

The form of fracture described above may be very well shown by breaking a stick of sealing wax transversely. It may also be shown by breaking a rod of glass transversely; and it may very often be seen in pieces of broken sheet glass. Take a piece of ordinary sheet glass, break it into two pieces with a transverse pressure, and then examine the fracture. It will, in many cases, be found that the surface of fracture is curved: one of the pieces will have a square corner on one side, and a rounded corner on the other, whilst the other piece will have a square corner on one side, and a very acute corner on the other side. This acute corner is sometimes drawn out to a very thin sharp edge; it is this sharp edge which makes broken glass so dangerous to handle. Closer observation will show that the square corners occur on that side which was in tension while the glass was under pressure; the rounded and the acute corners being on the compressed side. This curved form of fracture will not be observed in all cases, for it depends upon the position of the fracture with respect to the point where the pressure is applied.

Since this form is assumed by such widely different materials as cast iron, sealing wax, and glass, we may conclude that it is determined by something other than the material. What, then, determines this form of fracture?

Dynamicians tell us that when fracture takes place its direction must be along the line of least resistance, or perpendicular to the line of greatest traction, or a resultant of the two. It is very natural to suppose that these several lines would, in a square bar of uniform section, be all together at the center of the bar; but the observations show that this is not usually the case, and that fracture takes place away from the center more frequently than at the center. Even then it might be supposed that the fracture would be straight, and perpendicular to the sides of the bar, that being the shortest line, and, therefore, other things equal, the line of least resistance. But it is not so. Yet, whatever may be the position and direction of the line of fracture, it must be concluded that that line is the resultant of the line of least resistance, and the perpendicular to the line of greatest traction. Let us see whether any relation can be found between the line of fracture and the distribution of stress.

Some years ago, Sir George Airy made some researches into the distribution of stress in solid rectangular beams. He considered the stresses in a thin vertical lamina of a horizontal beam, supported at each end, and carrying merely its own weight. Such a beam would, of course, be carrying a uniformly-distributed load. By these researches he was led to the conclusion that the stresses were distributed through the beam along curvilinear paths. The curves for the two sets of stress are similar, but opposite; that is to say, the curves representing the tensile stress are concave upwards, while those representing the compressive stress are concave downwards, and the two sets of curves cross each other. These curves are shown in a diagram in "Rankine's Applied Mechanics," p. 342, Fig. 146, sixth edition, and are there called lines of principal stress. Some time ago I attempted to trace out these lines of principal stress with the aid of polarized light. To do this I used a glass bar, rectangular in section, 2 inches deep by 1 inch thick, and 1 ft. long. This was screwed into a frame, and pressure applied to it in such a manner as to imitate a distributed load. It was, while in this condition, put in the dark field of the polariscope in a known angular position, and a series of observations made and recorded. The angle was then changed and another series of observations made. This was repeated until a large number of points were obtained and laid on paper. The result showed that the two sets of curves crossed, that is to say, the curves representing tension crossed those representing compression at right angles to each other in all parts of the bar; and that there was no part of the bar without stress.

Now, then, how will these lines of principal stress help to explain the direction of the line of fracture? This way. Firstly, other things equal, the line of least resistance would be the shortest line across the bar, and would be perpendicular to the sides. The fracture would tend to follow that line. Secondly, other things equal, the line of fracture would tend to set itself at right angles to the lines of principal tensile stress. Now any line other than the center line crossing these curves at right angles, would itself be curved, and would be concave towards the center and downwards. It would, in fact, coincide with one of the lines of principal compressive stress. The fracture, then, tending to follow both of these directions, would follow neither, but would lie somewhere between the two; it would be a resultant of the two; and this is where observation finds it, for although it is curved in such a manner as to have its concave side directed towards the center of the bar and downwards, yet it is not sufficiently bent to set itself at right angles to the lines of principal tensile stress. When the fracture occurs in the middle of the bar, the line is straight, and perpendicular to the sides, because any tendency which may exist to bend it in one direction is balanced by an equal tendency to bend it in the opposite direction. In this position it is perpendicular to all the lines of principal stress as well as to the sides of the bar. This relation which the line of fracture bears to the line of least resistance and the lines of principal stress may perhaps be made clearer by a suitable diagram, which may be drawn in the following manner:—Make a copy of Rankine's diagram to a larger scale, omitting the lines of compression, and increasing the number of the lines of tension. Now, at a position midway between the ends, draw a perpendicular to the sides of the bar; this line will be perpendicular to all the lines of principal stress, because these lines are, in this position, horizontal; it will also be a line of least resistance; and it will be a line of central fracture. Again, draw on either side of the center a line of fracture as shown on the plate, or as described above for a 2-inch bar; then, from the lowest point of the fracture, draw a perpendicular to the sides of the bar; this will be a line of least resistance; from the same point draw a line, intersecting at right angles all the lines of principal tensile stress; this line will be curved, and will be concave towards the center of the bar and downwards. When these three lines are carefully drawn the line of fracture will be found to lie between the other two.

The observation of the three materials, cast iron, sealing wax, and glass, so curiously resembling each other in their line of fracture, has led me to inquire whether they have any other resemblance.

All bodies resist distortion. The particles of bodies having taken up certain positions, resist any force which tends to make them take up other positions; there can be no relative motion among them without the absorption of force; and if the force impressed upon them be sufficiently great to partly overcome, and yet not sufficient to completely overcome, the resistance, the particles return to their first position. The property which enables them to return is elasticity. By experiments on the elasticity of solid bodies it has been found that when the bodies have been distorted they do not completely return to their original shape after the removal of the distorting force; hence it is said that solids are not perfectly elastic bodies. Now this incomplete return shows that bodies possess another property which, in this phase at least, is opposed to elasticity. It does not, however, oppose elasticity in all its phases; for in its resistance to a distorting force it helps elasticity against the force, but when the force is removed it opposes elasticity, and prevents the body from returning to its original shape. It appears, then, that one of the functions of this property, which bears the name of viscosity, is to resist motion, or to absorb motion. This is also one of the functions of elasticity, for elasticity can absorb motion, but whatever motion it absorbs it can give out again as motion. In this way elasticity may be regarded as a reflector of motion. Not so, however, with viscosity; it cannot reflect motion; for having absorbed motion it cannot give it out again in the same form. Viscosity utterly destroys motion as such. But, although the motion disappears, no force is lost, for it is given out in another form; for viscosity has the power of transforming molar motion into molecular motion, or if the terms be preferable, of converting ordinary visible motion into heat. So that if motion be put into a viscous body, its temperature becomes raised. In this respect, viscosity resembles friction. In fact, it may be regarded as a kind of intermolecular friction.

Viscosity is possessed by fluids as well as by solids, for it is found in water and other liquids, in air and other gases; and it is even supposed to exist in the ether of space, the celestial ether which has been so triumphantly pointed to by the physicist as an example of a perfect fluid—a fluid which offers no resistance to a change of shape. Modern astronomy has shown that bodies of small mass, such as comets, are retarded in their motions through space; they do not come to their perihelion at the calculated time; hence it is inferred that they are ploughing their way through a resisting medium, and that the ether is a viscous fluid. The astronomer now turns round upon the physicist, and tells him that his perfect fluid is little better than so much diluted treacle.

Viscosity as observed in solids varies greatly in its range, both in different bodies at the same temperature, and in the same body at different temperatures. In some bodies its range is very wide, while in others it is very narrow; but in the majority of solids it is so extremely minute as to elude observation. In this respect, again, it resembles elasticity; for elasticity has in some solids, such as india-rubber, a very wide range; whilst in others, such as glass, it has a narrow range. When a solid is stretched beyond its limits of elasticity it suffers a permanent set. In like manner when a solid is stretched beyond its limit of viscosity it suffers breakage. The range of viscosity in a given solid body depends upon the temperature of the body and the speed with which a distorting force is applied. Take a stick of sealing-wax and bend it slowly with the fingers. With care it may be bent through a large angle. Now bend it quickly. It breaks. Lower the temperature; you find you have lessened its range of viscosity and increased its elasticity; and you have greater difficulty in bending it. Now raise the temperature higher than at first: you have at the same time increased the range of viscosity, and nearly destroyed the elasticity; and the sealing-wax may be bent in all directions with the greatest ease. Similar experiments might be made on glass with similar results. Glass when made hot enough to become soft is a highly viscous body, but when cooled down to the ordinary temperature of the atmosphere its viscosity disappears to general observation. It is nevertheless viscous to some extent even at a low temperature, as is shown by the fact that glass will suffer a permanent set under an insistent pressure. This may be illustrated by describing an observation which I made upon glass tubing some years ago. Having several pieces of glass tube, some about the size of barometer tube, some smaller, and about two feet long, I put them away in a box for future use. The box had a narrow strip of wood across the bottom which prevented the tubes from lying evenly, so that they rested about midway upon the strip, with one end touching the bottom of the box, leaving the other end free. On taking the tubes out of the box many months afterwards, I found they were all bent. They had suffered a permanent set, and that, too, under a very small pressure; but the pressure had remained on them a long time.

Now viscosity may be found in the metals. It may be found in lead, in copper, in silver, in gold, in wrought iron, in cast iron. You may remember that a few years ago the society visited Mr. Kirkaldy's Testing Works, and that during our visit Mr. Kirkaldy broke two pieces of wrought iron for our edification. Those two pieces of iron were totally unlike each other in their manner of breaking, and in the appearance of their fractured surfaces. One piece was very much elongated and diminished in the area of its cross section before it separated; the other was very little altered in this respect. The first showed a highly fibrous fracture; the second a cleavage fracture. The first broke silently; the second broke with a loud snap. The first was so hot immediately after breaking as to be unpleasant to the touch; the second was not perceptibly altered in temperature. The behavior of the first piece showed that it had a considerable range of viscosity; in the second the range was reduced to a minimum. The overcoming of the viscosity in the first piece generated the heat, which raised the temperature of the iron. Those two pieces showed that the viscosity of wrought iron varies considerably in different samples, even at the same temperature. But it varies far more at different temperatures; for if wrought iron be made red-hot or white-hot it is made highly viscous, and may, as is very well known, be hammered out or rolled out to any extent. This hammering or rolling, doing work upon the iron by overcoming its viscous resistance, generates heat in the metal, and keeps up its temperature. The effect of this may be observed at a rolling-mill, where a bar of iron may be seen to be visibly hotter immediately after passing through the rolls; but this accession of heat does not last long, for radiation is very rapid at this high temperature, and soon dissipates the heat. We see, then, that wrought iron is a highly viscous metal, and viscosity is one of the properties which help to give wrought iron its great value.

By the addition of a little carbon to wrought iron the metal is converted into steel, and its viscosity is very much diminished. By increasing the quantity of carbon, the metal becomes less and less viscous, until it is at length converted into cast iron, and then its viscosity almost disappears. But it is not entirely gone; for, if a bar of cast iron be made red-hot, it may, with care, be slightly bent. True, it cannot be bent very much; but the bending, however little, is sufficient to show that the metal is to some extent viscous. Small as this little viscosity is in hot cast iron, it is still less in the cold metal. It can, nevertheless, be found, for experiments on the strength of cast iron have shown that when strained, it suffers a permanent set, and this is only another way of saying that the metal is viscous; for without viscosity, there could be no permanent set.

So much, then, for viscosity; we pass now to regelation.

Regelation is a property which is very generally regarded as being peculiar to ice. It does not appear to have been observed in any other kinds of matter; or, if observed, nobody says anything about it. The regelation of ice has attracted a very large amount of attention on account of the part which it plays, and the great scale of its operations, in the motion of glaciers. A glacier moves like a river: it moves faster in the middle than at the sides; it bends round corners and other obstacles; it contracts its dimensions at narrow places, and widens out to fill its bed at wide places, in the same way as a river does, only it does not move so fast as a river. In fact, a glacier is now generally regarded as a solid river. Now to explain this remarkable behavior of a glacier two theories have been propounded: the first accounts for the motion by supposing that ice, although a solid, has a certain amount of viscosity which enables it to move like a fluid; the second, which is the more popular, denies the viscosity and brings in regelation to explain the motion. Regelation will explain a great many of the phenomena of glaciers, but will not explain all; and I think it will some day be found necessary to unite the two theories; for regelation is a great putting-together property, and viscosity, in virtue of the resistance with which it offers to change of shape, is a great holding-together property, and the phenomena seem to need the assistance of both. Let us observe a few of the results of regelation, and then consider what are the conditions necessary to its operation.

A boy takes a handful of newly-fallen snow, and presses it into a snow-ball; but he finds that after the snow has lain on the ground all the night and has been frozen, his snowballing propensity has received a check; for he can no longer make the particles of snow cohere. A physicist will take some snow or pounded ice, and with his Brama press will squeeze it into a solid block of transparent ice; or he will take two blocks of ice, and pressing them together with his hands, make them unite to form a single block. One of the prettiest experiments which has come under my notice is to lay a bar of ice horizontally upon two bearings at its ends, then place a thin wire upon the middle of the bar, and hang a weight to it. The wire will in time cut its way through the bar, and come out at the under side without leaving a trace of its path. These are some of the phenomena of regelation; how are they to be explained? or what are the conditions necessary to be present in order that regelation may ensue?

Some years ago Professor James Thomson showed, as a result of some researches into the laws of heat, that if certain (now well-established) laws of thermodynamics were true, then water under pressure would have its freezing point lowered in the scale of temperature. Sir William Thomson put this to the test of experiment, and found that the freezing point of water was lowered one-seventieth of a degree on Fahrenheit's scale for every additional atmosphere of pressure; proving that his brother's deduction was right. Some physicists, using this discovery to explain regelation, say that if a quantity of snow or pounded ice be pressed together, its freezing point will be lowered, and some of the ice melted; then when the pressure is removed the freezing point will return to its normal position, and the water be frozen. The wire passing through the bar of ice is explained on this theory by supposing that the pressure of the wire upon the ice lowers the freezing point of the small portion upon which it presses; the resulting drop of water then passes round from the under side to the upper side of the wire, where, being free from pressure, it freezes again; and as this is continuous, the wire leaves no trace of its passage through the bar. Other physicists say that since it requires such an enormous pressure to lower the freezing point of water in any perceptible quantity, the pressures usually applied are not sufficient to account for regelation. They seem to disregard the fact that a great many of the forces which are combined to work under the laws of nature are individually so small as not only to elude ordinary observation, but to baffle the best observers, even when using the most refined methods which science can devise. It is a mistake not to bear this in mind; and it should not be forgotten that many of the great operations of nature are performed by the addition of a number of very small forces, and that some of the grandest results are brought about by the indefinite accumulation of infinitesimal quantities.

Now it appears to me that regelation is a quantity with two factors, either of which may vary inversely as the other. One factor has already been described; the other, which does not appear in the books, perhaps because authors think it so obvious as not to need any special mention, is the following: According to the laws of thermodynamics, motion is convertible into heat in equatible quantities. If a dynamical pressure be applied to a resisting body so as to overcome the resistance and change the shape or volume of the body, or both the shape and the volume, heat is generated in the body. In the experiments which physicists perform upon snow and pounded ice with the Bramah press a considerable amount of pressure is applied; and since the shape of the ice is very much altered, as well as its particles being squeezed closer together, heat is generated in the ice. The motion of the ram is arrested by the ice, and transformed into heat. This heat must either raise the temperature of the ice or melt some of it, according to the temperature at the beginning of the experiment, whether it be below or at the melting point. In the formation of snowballs, and the pressing of two pieces of ice together with the hands, the snow and ice are very near the melting point; but when the boy fails in his attempts at making snowballs he fails because the snow is too cold, and he cannot apply enough pressure to raise its temperature to the melting point. Put the snow into a mould, and apply sufficient pressure to raise its temperature to the proper height, then it will bind together. You see, then, that in order to effect regelation, the temperature must be brought near the melting point; and this may be done in two ways at one operation, namely, by applying sufficient pressure to lower the melting point and to raise the temperature, when, if the operation be carried far enough, some of the ice will be melted; then remove the pressure, and the water will be frozen again, because its freezing point is raised, and any surplus heat is radiated away from it. The amount of pressure needed, according to this view, depends upon the temperature of the ice at the beginning of the operation. It appears, therefore, that the temperature at which regelation may take place can vary within very narrow limits. The temperature within these limits may be called the "temperature of regelation," or the "regelative temperature," whichever is the most convenient, as it will be wanted further on.

But why make regelation the peculiar property of ice, to the exclusion of all other kinds of matter? Why not examine other kinds of matter to see if they exhibit any similar property when placed under like conditions? For a long time after it was understood that ice floats upon water because it expands at the instant of solidification, it was taken for granted that water stood alone in this respect, and that nothing like it was to be found in the whole region of matter. It is now known that other kinds of matter behave like water when passing from the liquid to the solid form; and among them may be mentioned some of the metals, as for instance, brass, cast iron, lead, and some of its alloys. Now it appears that this phenomenon of a solid floating upon its own liquid, with which we are all familiar in the sea of ice floating upon water, this increase of volume at the instant of solidification is intimately connected with regelation; and if the two phenomena are connected we ought to find regelation in some of the metals. Let us see what can be found. We need not make any delicate experiments in the laboratory, for we may observe the phenomena as exhibited on a larger scale in the operations of the workshop. We may begin with lead, and note how it is treated in the manufacture of lead piping.

The lead pipes which are used in our houses for conveying water, and for other purposes, are made in the following manner: A strong iron cylinder is fixed with its axis in a vertical position. A ram works in it underneath, and there is a hole in the upper end of the cylinder for receiving a die. The die is made of such a size as to give the required diameter to the lead pipe. The ram is lowered and the cylinder is filled with melted lead. The lead radiates its heat through the cylinder, but in order that it may not cool down below a certain temperature, a fire is kept burning around and in contact with the cylinder. When the lead is cooled down to a little below its point of solidification, and is "set," as it is technically called, pressure is applied to the ram, and the lead is forced through the die. If the pressure be applied before the lead is sufficiently cooled, or before it is "set," a jet of liquid metal is thrown up, and a splash of lead is left on the ceiling above the cylinder, as evidence that that part of the operation was begun too soon. If the die were simply a round hole, a solid rod of lead instead of a pipe would be pushed through it, so the die is made of annular form by the insertion of a steel core in the center of the hole. But this core has to be held in position. This is done by a bar across both the core and the die inside the cylinder, so that the core cannot be forced out through the die. The lead in its passage from the cylinder has to move round this bar; for the bar acts somewhat like an island in the middle of a river; or like an island in the middle of a glacier; it cuts the stream into two halves. How are these two streams of lead to join each other so as to make a pipe? We have seen that if the lead be liquid, a jet is thrown up, and instead of forming a pipe, falls as an unpleasant shower upon the workmen. If the lead were solid, its ductility would enable it to be forced through the die in the form of two half-cylinders; but ductility would not join the two halves together. How, then, is the joining effected? I see no way of doing it except by regelation; and that regelation does really take place appears clear when we examine the conditions of the operation. The conditions are: the lead must be "set," that is, it must be solid; and it must be kept as hot as it can be without melting. What is this but keeping it near the regelative temperature? Further, pressure must be applied to force it through the die. It appears, then, that the lead is forced against the die with a pressure which slightly lowers its melting point; and, as the pressure overcomes a viscous resistance, heat is generated in the lead, thus slightly raising its already high temperature; these two causes acting together melt a portion of the lead. Then, before the lead gets quite through the die, the resistance diminishes; therefore the pressure diminishes; and as the pressure diminishes the melting point returns to its normal height; meanwhile, that portion of the lead which is escaping the pressure is coming nearer to the external air; its temperature is therefore being lowered, because its heat is radiated more rapidly; these two causes acting together solidify the lead—that is, regele the lead, and complete the formation of the pipe. In this way a lead pipe is formed by regelation. Regelation, then, is a property which the lead-pipe maker turns to his advantage; and in order that he may do so he recognizes the importance of working with his metal at a proper temperature.

Now, is this property to be found in any other metal? I think it is; but its phenomena are too common to attract attention; for how is the welding of wrought iron accomplished if not by regelation? Welding is so well known that a description of it here would be needless; and you can easily see for yourselves how much it resembles regelation.

Having traced out regelation, as exhibited in lead, and noticed its existence in wrought iron, can we find it in cast iron? It is well known that cast iron cannot be welded, nor worked in any way at the forge; but I had noticed, among the many phenomena displayed in the foundry, two or three points which led me to think that a trace of regelation might, if properly sought, be found in cast iron. With this in view I made some experiments upon cast iron at a high temperature. In these experiments I was very ably joined by the foreman of the moulders, who, after receiving my explanation of what I wanted to find, took a warm interest in it, and gave me some very useful assistance; but notwithstanding all our care in bringing about the requisite conditions, and in excluding, as far as possible, the disturbing influences, our attempts failed to disclose anything that could be called regelation. Reflecting upon these experiments, I began to consider what are the conditions necessary to the successful welding of wrought iron. The conditions are, a proper temperature, a clean fire and pressure. Now, the clean fire gave a clue to the discovery of the secret. It is known to every smith that certain matters getting into his fire will spoil it for welding; among these are sulphur, lead, brass, and to a less extent, cast iron. What is there in cast iron that can spoil the fire for welding? It cannot be the carbon, because carbon is one of the most important elements used in making a fire. What, then, is it? Let us trace out the phenomena. With a clean fire a smith finds no difficulty in welding good wrought iron; but he finds a little difficulty in welding spring steel, that is, iron containing a little carbon; with a little higher quality of steel he finds a little greater difficulty; and as the steel gets more steely, that is, as the iron contains a larger and larger percentage of carbon, so the difficulty of welding increases; until, when the iron contains as much carbon as it can take up, and thereby becomes cast iron, it cannot be welded at all. The evidence points strongly towards the carbon as being the disturbing agent; and yet the carbon which is burnt in the fire exercises no disturbing influence. But the carbon in cast iron is not in the same form as the carbon in the fire: in the fire it takes the ordinary combustible form; in cast iron it takes the form known as graphite. This difference of form might make all the difference in its influence upon welding. Smiths sometimes dip the iron which they are heating into sand, to prevent the projecting corners from burning away before the iron is hot enough throughout the surfaces which they intend to weld together; and the sand does not prevent the welding. Remembering this, I thought if two pieces of wrought iron were similarly dipped into some powdered graphite, it would serve as a test of the influence of graphite upon welding, and therefore upon the regelation of iron. Acting upon this thought, I induced a smith to make an experiment, under my observation, in the following manner: he took two pieces of wrought iron and welded them together, in order to show that his fire was clean, or to show that there was nothing in his fire which could spoil the welding; he then cut the bar into two pieces a few inches beyond the weld, and heated them again; this time he dipped the two hot ends into the powdered graphite, and then tried to weld them together, but failed; for the two pieces of iron would not unite. You see we had throughout the experiment the same fire, the same iron, the same everything, except the graphite; when the graphite was *not* used the welding was successful; but when the graphite *was* used the welding failed. So it turns out, after all, that carbon is the disturbing element which prevents the regelation of cast iron; and in order that it may exert its influence it must be in the form of graphite, that form in which it is found in cast iron.

PRACTICAL RULES FOR THE USE OF TELEODYNAMIC CABLES.

By M. LEAUTE.

Translated from "Revue Industrielle" for VAN NOSTRAND'S MAGAZINE.

IN order to insure a satisfactory transmission of power by cables, it is not sufficient that the rope should be merely capable of resisting the tensions to which this use subjects it, but it is also necessary that it should insure uniformity of action. In other words, it is necessary to take into account at the same time, the conditions of resistance of the cable and those which relate to regularity of motion. This is not at present done; for in the formulas now in use regularity of movement is not taken into account.

It is then necessary to reconsider this problem, and to take into account both of these conditions, and since the regularity is intimately related to the deflection $\frac{f}{2l}$ (f being the deflection of one of the strands of the cable, and l the half span between supports) the first thing to be done is to determine the value to be admitted for each case of this quantity.

The deflection which may be as much as $\frac{1}{15}$ or $\frac{1}{20}$ for small distances of 20 or 30 meters ought not in some cases to be more than $\frac{1}{40}$.

From a number of experiments made by M. Berard at Pont de Buis, it appears that with weak cables, the accidental variations of length, due to changes in temperature and humidity, give rise to so great variations in deflection as to subject the machinery driven to some danger.

We will add that these variations in deflection modify at the same time the coefficient of regularity, and change thereby the conditions of transmitting the power.

Whatever it be, the relative deflection should be fixed in the first place. If we designate it by m, and the deflections of the conducting and returning ropes respectively F and f; also by k the ratio between them (which should be at most equal to 2 to avoid slipping), we have

$$f = k\text{F}$$

and

$$f^2 + \text{F}^2 = 8m^2l^2$$

by reason of the inextensibility of the cable.

We deduce from this

$$\text{F} = 2ml\sqrt{\frac{2}{1+k^2}} \qquad f = 2mlk\sqrt{\frac{2}{1+k^2}}$$

The tensions of the two branches are furnished by the equations

$$a\text{T} = \frac{pl^2}{2\text{F}} = \frac{pl}{4m}\sqrt{\frac{1+k^2}{2}}$$

$$at = \frac{pl^2}{2f} = \frac{pl}{4m}\frac{1}{\text{K}}\sqrt{\frac{1+k^2}{2}}$$

where p is the weight of the cable per meter, and a the mass of a unit of length.

If now we let N represent the number of horse-powers transmitted, and V the velocity of the cable

$$\frac{75\text{N}}{\text{V}} = a(\text{T}-t) = \frac{pl}{4m}\sqrt{\frac{1+k^2}{2}}\left(1-\frac{1}{k}\right)$$

from which we deduce for the value of p in kilogrammes, V and l being in meters

$$p = \frac{300m\text{N}}{\text{V}l\left(1-\frac{1}{k}\right)\sqrt{\frac{1+k^2}{2}}}$$

The area of the section in millimeters, if the material is iron with a density of $\frac{1000}{114}$ would be

$$\text{S} = 114p = \frac{34{,}200\,m\text{N}}{\text{V}l}\,\frac{k}{k-1}\sqrt{\frac{2}{1+k^2}}$$

We can deduce from this the tension proportioned to the square millimeter in the conducting rope. We have then

$$\text{U} = \frac{a(\text{T}+\text{V}^2)}{\text{S}} = \frac{l}{456m}\sqrt{\frac{1+k^2}{2}} + \frac{\text{V}^2}{114g}$$

As for the tension in the cable occasioned by the passage over the pulleys, it is known to be

$$u = \frac{20{,}000\,d}{\text{D}};$$

d being the diameter of wires forming the cable and D being the diameter of the pulley, both in millimeters.

If we assume 15 kilogrammes as a maximum strain per square millimeter, we have the equation

$$\frac{20{,}000\, d}{D} = 15 - U$$

which affords the value of d on terms of D.

The diameter of the wire being obtained, we may find their number by the equation

$$i = \frac{4S}{\pi d^2} = 145\frac{p}{d^2}$$

which completes the determination of the cable to be employed.

MEANS ADOPTED FOR RANGING THE CENTER LINE OF THE ST. GOTHARD TUNNEL.

By C. DOLEZALEK, Section-Engineer of the St. Gothard Railway.

From Abstracts published by Institution of Civil Engineers.

The axis of the St. Gothard tunnel is a straight line about $9\frac{1}{4}$ miles long, with rising gradients of 1 in 172 and 1 in 1,000 respectively from both ends towards its center. At its extremities, viz: in Göschenen and Airolo, observatories were erected, distant 585 and 358 meters respectively from the tunnel portals, in which were set up the transit instruments previously used in laying out the Mont Cenis tunnel.

The direction of the center line is given from the observatory at night by a lamp placed over that point in it, inside the tunnel, which can be accurately observed directly, its ranging being thence produced by a theodolite as far as the heading permits. A direct observation as far into the tunnel as possible is therefore of the greatest importance, and to obtain this as well as longer station lengths for the ranging in the interior of the tunnel, the Author devised the contrivances which form the subject of this paper.

In 1875, to allow the signal to be shown at the right moment to the observer, telegraphic communication was established between the portal and the observatory, in both of which batteries with Morse's instruments were set up, while, in the unfinished tunnel itself, a wire was joined on by the use of portable field telegraphs.

As petroleum lamps with a bright flame proved far superior to common miners' lamps for signaling at long distances, the Author constructed with the brilliant-burner ("Rundbrenner") of Schuster & Baer of Berlin, which gave on trial 1.8 time better illumination than the ordinary petroleum lamp. This burner has a double set of pinions moving two half wicks with the greatest regularity, and is screwed on to a large metal vessel having what is called a "double-vase ring." As this allows petroleum to be afterwards poured in without unscrewing the wick-holder, the centering of the lamp (over any station) is not thrown out during the whole period of its use, since the openings in the two rings can be made to coincide or not, at will. The vessel is now leveled on a movable bronze tripod, their centers being made accurately to coincide. This concentric position is in the first instance secured by the maker, but if thrown out at any time, the ring, on which the lamp rests, can be so set by small screws, moving in a circular slit, that the middle of the wick shall be concentric with the tripod, the ring in this case being eccentric to it. This adjustment, however, ought not to be necessary if the lamp is carefully handled. A cylindrical metal mirror is provided to intensify the brilliancy of the flame. This signal lamp surpassed all others in giving far longer station lengths under similar conditions; but it may even yet be advisable to devise apparatus for using the electric light in its place.

To diminish still more the delays and inaccuracies incident on such frequent settings-up of instrument and signal in the tunnel, the Author further constructed a stand applicable to either. It is in two parts, a top plate of metal resting on a larger circular one of wood to which three legs are attached. This top plate is separate from the lower one, though capable of being centered accurately with it under or over any required point inside the tunnel, such point being denoted by a notch on an iron cramp, which is driven into the ground. The weight (nearly 31 lbs.) of the metal plate ensures its steadiness, as its three pointed foot-screws work in small cups let into the wooden plate; by these it is leveled, and when the lamp is placed on it for use, it can be turned round and clamped in any direction.

Every station in the center line was fixed by the mean of eight distinct settings-up of the lamp, by which all level and collimation errors were eliminated from the observations. To deduce this mean readily, the metal plate consists of a bronze plate sliding in a cast-iron frame and provided with a clamp and tangent screw. The center of the bronze plate is given by a notch on either side, while to the two edges of the cast-iron frame strips of gummed paper are affixed, on which each observation is to be recorded by a pencil mark. To the mean of these marks the center of the bronze plate is now set by the notch, and in order that it may necessarily be coincident with that of either lamp or theodolite, as each is successively set up upon the plate, three small grooves radiate from it at angles of 120°, in which are secured the feet of either instrument of whatever size. At the next station the used paper-strips are scraped off, and fresh ones affixed. A plummet and line are attached to the stand for centering purposes.

The advantages claimed for this stand lie in the remarkable speed of "setting-up," in the elimination of all possible errors in the operation, and in the ready insertion of the lamp upon it on the center line; it is also easily carried about the tunnel packed in a chest. The wooden portion is only 1 meter high besides the round wooded plate of 0.5 meter outer, and 0.34 meter inner, diameter. Lead weights are attached to the lower parts of the legs to keep them steady if accidentally pushed. Weights above 20 kilogrammes (44 lbs.) should be made up from smaller ones to facilitate their manipulation; and since all the material, instruments, &c., are always forwarded from point to point in the tunnel on trollies, the transport of these lead weights offers no difficulty.

A light transit without vertical and horizontal circles, but with a powerful telescope magnifying thirty times, is advocated for ranging purposes inside the tunnel, and by its use great rapidity in the work is anticipated.

REPORTS OF ENGINEERING SOCIETIES.

Boston Society of Civil Engineers.—The latest published transactions that have reached us are:

"Production and Transmission of Power by Electricity," by Geo. W. Blodgett.

"Rock Blasting and Machine Drilling," by William Whittaker.

Engineers' Club of Philadelphia.—Record of Meeting April 17th.

Mr. Frederic Graff, C. E., President, in the chair.

Mr. Coleman Sellers, Jr., M. E., read a paper on the history of the construction of the Mexico and Vera Cruz Railroad, illustrating his remarks with numerous photographs and maps obtained during a recent trip to the country of the Montezumas. As early as 1837 the project was broached, and from that time until it was finally opened in 1873, by President Lerdo, the road suffered an alternation of successes and defeats. During its progress forty different Presidents and one Emperor governed our unfortunate neighbor, and each government had, in turn, to be won over to the plans of the friends of this enterprise, and that in spite of a powerful opposition from various classes of the community. Not only were these difficulties surmounted, but those offered by the climate and the natural obstacles of the route were likewise overcome. At length, after years of labor, and the expenditure of millions of money, the road is now an established success; and is to-day one of the grandest specimens of engineering the world can show. The road is 260 miles long; is laid with steel rails; is thoroughly equipped with engines and rolling stock; has fine iron bridges, substantial stone stations and all tunnels, masonry, &c., and of the best character. The grades and curves are numerous and excessive. The highest point of the road is 8,200 feet above the sea. It ascends 6,500 feet in sixty miles, and in one case climbs 2,000 feet in fifteen miles.

Mr. Chas. G. Darrach, C. E., read an extract from a law recently passed by the State of Wisconsin, making it a crime to allow any sewage or unhealthful matter to be deposited in the rivers running through the City of Milwaukee, entitled, "An Act to preserve and promote the public health in the City of Milwaukee." He called attention to the interest now being taken by the City of Chicago upon the same subject, and read an extract from a recent work on sewerage by Julius W. Adams, C. E.

The regular business meeting of the Engineers' Club of Philadelphia was held on Saturday evening, May 1st. The following was presented by Mr. C. E. Billin, C. E.:

"The present condition of the profession of land surveyor in our State, the want of accurate knowledge in regard to county and other boundaries, and the very erroneous county and state maps current, are a disgrace to Pennsylvania and to its engineers. The club cannot possibly undertake any more needed work of reform and improvement. The attempt to improve upon present methods and results in any engineering work, however humble, should call forth hearty approval and earnest work from the club. In furtherance of the remarks and suggestions which I made at the meeting of the Club, held March 20th, I would respectfully move:

"'That a commmittee of five members be appointed by the Chair, who shall take into consideration the subject of the improvement of the present methods of land surveying, the better location of county and other boundaries, and the collection of information in regard to the geography and topography of the several portions of the State.'

"'That they shall be empowered to take such action as may appear to them as will lead to the best results in the promotion of the end in view; provided that they incur no expense to the club, except under special appropriations.'"

The following was presented by Mr. Chas. G. Darrach, C. E.:

"Resolved, That the President be requested to appoint a Committee of five, one of whom to be the Chief Engineer and Surveyor of the City, to study and suggest a plan of improved sewerage for the City of Philadelphia, and the protection of the rivers from pollution." The resolutions were passed, and Mr. Frederic Graff, C. E., President of the Club, will announce the above Committees at the next meeting.

Prof. L. M. Haupt, C. E., read a paper in favor of Rapid Transit in Philadelphia, showing the desirability of the improvement, and that the objections thereto were of the same character as those usually urged against progress.

IRON AND STEEL NOTES.

Manufacture of Steel.—An improved process for manufacturing a high quality of steel or ingot iron, by a combination of the Bessemer and open hearth process, from pig containing much phosphorus, or phosphorus and sulphur, has been patented by Mr. E. P. Martin, of Blaenavon. He blows the molten pig in either a vertical or tipping Bessemer or other converter, with an ordinary silicious lining till nearly all the silicon is removed. He prefers to stop the blow two or three minutes before the drop of the flame. He then runs the metal (without the slag) either directly through a runner, or by the intervention of a lade, into a Siemens, Pernot or other open hearth furnace (preferably a Pernot or other rotating gas furnace). This open hearth furnace must be lined with basic material (preferably Thomas's magnesian lime bricks), and have spread on its hearth a large quantity of limestone or of lime, which he always prefers to mix with a large quantity (preferably an equal weight) of oxide of iron, so as to produce a highly basic calcareous slag, which may advantageously contain over 40 per cent. of lime and magnesia. By the action of these bases the phosphorus and a considerable amount of the sulphur are rapidly removed. The greater the agitation the more rapid will be the dephosphorization. When the charge has been brought to the desired pitch, as indicated by the fracture of a sample showing the phosphorus to be removed, the slag is tapped off before the spiegel or ferro-manganese is introduced. A part of the charge in the open hearth furnace may consist of scrap iron. A very high quality of steel may be thus produced from the cheapest materials. Mr. Martin claims not the mere dephosphorizing by basic additions, but the improved combined process described for the manufacture of steel from phosphoric pig-iron. —*Iron and Steel.*

Iron and Steel at low Temperatures.—At the meeting on Tuesday, the 10th of February, of the Institution of Civil Engineers, Mr. W. H. Barlow, F. R. S., President in the chair, a paper was read on "Iron and Steel at low temperatures," by Mr. John James Webster, Assoc. M. Inst. C.E.

The first part of the paper treated of the generally received opinion as to the condition of iron and steel at low temperatures, reference being made to the evidence given before the Royal Commission appointed to inquire into the application of iron to railway structures, and to papers read before the British Association and elsewhere. An account followed of the results of experiments by the late Sir W. Fairbairn; after which, the elaborate series by M. Knut Styffe were mentioned, and the conclusions he arrived at were stated *in extenso.* From the results of these tests as to tensile strains, it appears that the absolute strength of iron or steel was not influenced by severe cold, but that the ductility of these materials was increased. Mr. C. P. Sandberg had submitted rails of iron and of steel to a force of impact, and his deductions were quoted.

The author then gave an account of the experiments he had made on bars of wrought iron, cast iron, malleable cast iron, Bessemer steel, and best cast tool steel, with a description of the apparatus used, and of the method of conducting the experiments. The bars were tested with tensile and transverse strains, and also by impact; one-half of them at a temperature of 50 deg. Fahr., and the other half at 5 deg. Fahr. The lower temperature was obtained by placing the bars in a freezing mixture, care being taken to keep the bars covered with it during the whole time of the experiments. The results were given in eight tables, and the averages of all in a ninth table.

Three sheets of diagrams accompanied the paper; the first sheet illustrated the testing apparatus; the second and third sheets showed the extensions of the bars at the different portions of their length, the appearance of the fracture, and the percentage of elongation and of reduction of area. The results of the experiments were summarised as follows:

1. When bars of wrought iron or steel were submitted to a tensile strain and broken, their strength was not affected by severe cold (5 deg. Fahr.), but their ductility was increased about 1 per cent. in iron and 3 per cent. in steel.

2. When bars of cast iron were submitted to a transverse strain at a low temperature, their strength was diminished about 3 per cent. and their flexibility about 16 per cent.

3. When bars of wrought iron, malleable cast iron, steel, and ordinary cast iron, were subjected to impact at a temperature of 5 deg. Fahr., the force required to break them, and the extent of their flexibility, were reduced as follows, viz.:

	Reduction of Force of Impact. per cent.	Reduction of Flexibility. per cent.
Wrought iron, about	3	18
Steel (best cast tool), "	3½	17
Malleable cast iron "	4½	15
Cast iron "	21	not taken

The paper closed with a review of the experiments described, with some remarks on the conclusions arrived at, and with a statement of the opinions formed by different authorities.

A case of samples of the fractured ends of the bars used in the experiments was exhibited.

Bessemer Steel.—Before the adoption of the Bessemer process in the production of steel the entire production of cast steel in Great Britain was only about 50,000 tons annually, and its average price, which ranged from £50 to £60 per ton, was prohibitory of its use for many of the purposes to which it is now universally applied. In the year 1877, notwithstanding the depression of trade, the Bessemer steel produced in Great Britain alone amounted to 750,600 tons, or fifteen times the total of the former method of manufacture; while the selling price averaged only £10 per ton, and the coal consumed in producing it was less by 3,500,000 tons than would have been required in order to make the same quantity of steel by the old or Sheffield process. The total reduction of cost is equal to about £30,000,000 sterling upon the quantity manufactured in England during the year; and in this way steel has been rendered available for a vast number of purposes in which its qualities are of the greatest possible value, but from which its high price formerly excluded it. During the same year the Bessemer steel manufactured in the five other countries in which the business is chiefly conducted—namely, the United States, Belgium, Germany, France, and Sweden—raised the total output to 1,874,278 tons, with a net selling value of about £20,000,000 sterling. The works in which these operations are carried on were eighty-four in number, and represent a capital of more than three millions. According to the calculations of Mr. Price Williams, who has made the endurance of rails a matter of careful study, the substitution of Bessemer steel for iron for this purpose alone will produce a saving of expenditure during the life of one set of steel rails on all the existing lines in Great Britain of a sum of more than one hundred and seventy millions sterling. It may safely be said that there is no other instance in history of an analogous impetus to manufacture, or of an analogous economy, being the result of the brain-work of a single individual; still less is there an instance of such results being realized while the inventor was living to enjoy the fruits of his labors, and able to work in fresh directions to increase the benefits which he had already conferred upon his country and upon mankind.—*Times.*

RAILWAY NOTES.

Asiatic Railways.—Sir Richard Temple is still supervising all the arrangements along the Bolan route. He left Quetta on the the 9th for Candahar. Active steps for railway extension are being taken in the Khyber line also, and Mr. Molesworth, Government Consulting Engineer for State Railways, has been ordered to examine the country from Peshawur to Jellalabad. The Sukkur-Dadur Railway is now completed as far as Jocobabad and is being rapidly pushed on towards Quetta. It is stated that the broad gauge will extend only to this end of the Bolan Pass, the line being continued thence on meter gauge. It seems, however, hardly possible that the Government will sanction the break of the gauge on a line of such strategical importance. The permanent way and engines, it is believed, have been already ordered in England, and at the present rate of progress, of over a mile daily, the railway should be open to Quetta before many months. There is little doubt but that it will be eventually extended to Candahar. The *Daily News'* correspondent at St. Petersburg sends some details from the *New Times* as to the proposed railway from Orenburg to Tashkend. This purely strategical line will be 1,650 miles in length, and will cost, according to the Russian journal, about £11,500 a mile, at the present value of the rouble. Here we have a proposed expenditure of nearly £20,000,000, at what must be considered a very low estimate even for a single-track railroad in such a barren rugged country. That it can pay interest on its cost within any reasonable period is impossible; but this is to be remedied by the guarantee of 5 per cent. interest by a Russian railroad bank.

Endless Rails.—The idea of making a train lay down and take up its own rails as it moves along is not a new one, but an interesting realization of it is now to be witnessed (we learn from *La Nature*) in the Jardin des Tuileries, Paris. The system is that of Clement

Ader. The rails on either side of the carriages consist of a series of joined pieces of rail with flat supporting pieces; they enclose the system of wheels, passing down over the front and up over the end wheels, and all the wheels have two flanges to prevent any derailment. In front the chains of rail are guided by two distributing wheels, which are governed by the traction, so that, on pulling obliquely, right or left, the endless way automically follows the same direction. At the end of the train, again, are two taking-up wheels, provided with a differential motion to meet the difficulty of going in curves, which involves an extending of the rail on one side and contraction of that on the other, so that, whatever the curve (to six or seven meters' radius), the way is regularly put down and lifted. From the mechanical point of view, one is struck with the smallness of the force required to move a train thus arranged. In the Jardin des Tuileries the train consists of three carriages, capable of containing in all 30 children, and often full. These are drawn by two goats, which work thus for seven hours. The total load is about 1,000 kilogrammes. To draw a like weight in three carriages on ordinary roads would require a dozen goats, four for each vehicle (this is the number harnessed to the small carriages for children in the Champs Elysées). The economy of carriage, then, is incontestable. The normal speed is four to six kilometres per hour. The system is, of course, not designed for passenger traffic, but for goods, and in many places with bad roads or none might be very serviceable.

THE RAILROAD OUTLOOK.—*The Iron Age*, in an elaborate and careful examination of the prospect for railway building in the United States in 1880, reaches the conclusion that indications point to the construction of about 7,000 miles of new road, rather more than fewer, and that the demand during the year for new rails, to be used for new roads and old tracks, will reach 1,500,000 gross tons, of which the American mills can supply, under favorable circumstances, not more than 1,400,000 tons, leaving 100,000 tons to be imported.

SOUTH AUSTRALIAN RAILWAYS.—South Australia has now 533¼ miles of railway in working, and 475¼ miles either in course of coustruction or authorized. Alterations and additions are being effected at the Adelaide station-yard, with a view to accommodate the traffic, which will be increased as soon as the Holdfast Bay Railway, now in course of construction by a private company, is connected with the Government lines. An additional line of rails has been authorized to be laid between Adelaide and Port Adelaide. The requisite permanent way material is expected to arrive shortly, and the culverts and earthworks are in hand. Designs have been submitted for a new passenger station at Port Adelaide in which the present building will be utilized so far as is practicable. One mile of the railway has been relaid with 61 lbs. steel rails. At the Adelaide station which has been almost entirely rebuilt during the year, an hydraulic lift has been erected. An arrival platform, with additional luggage-room and engine traverser, to meet the extra traffic caused by the Holdfast Bay and Nairne lines, are fast approaching completion.—*Engineering*.

ENDLESS-CHAIN MINE RAILWAY AT FILLOLS.*—The iron mines at Fillols, in the Canigou region, Eastern Pyrenees, are situated at a high elevation, from which the minerals are conveyed by gravitation, in small wagons on a double line of railway, with endless chains. The system extends over a distance of 5 miles in direct length, between the highest point, called Salvé, and the station at Prades. The undulations of the surface are followed, for the most part, though here and there holes are filled up, and humps are removed. The railway consists of seven inclined planes, on which two lines of way are laid to a gauge of 21⅔ in. between the centers of the rails. The rails are of Bessemer steel, 14 lbs. per yard, fished-jointed, and laid on transverse sleepers, 30 in. apart. The difference of level at the mine and Prades station amounts to 984 ft. The inclines, direct and reverse, vary from a level to 23 cent., or nearly 1 in four; they are connected by short pieces of level line. A directing pulley is placed at the end of each incline, and the system is automatic; as the loaded wagons, descending by gravitation, draw up the empty wagons. Each wagon weighs 500 lbs., and carries a load of ½ ton. The speed is limited to 3.35 miles per hour, at which rate 300,000 tons per year can be transported. The wagons are controlled by means of four breaks with return pulleys.

The chains consist of ring-links, and weigh from 8 lbs. to 20 lbs. per yard, according to the maximum degree of tension on the different planes. The chain is supported on the wagons, and is attached to each wagon by a fork, between the sides of which one of the links enters. The chain is thus entirely supported by the wagons, and is suspended or floated (*chaine flottante*). The loaded wagons leave the chain at a distance of a few yards before the pulley, which is raised sufficiently high to lift the chain out of the fork, and arrive quietly on tables. The wagons are pushed on down a slight incline to take the next length of chain, or if it be removed at this platform, are turned aside and replaced by empty wagons.

The first cost of the floating chain system of transport amounted to £1,276 per mile. The cost for transport varied from ¾d. to 2¼d. per ton conveyed per mile. The cost for the whole distance, 5 miles, taken at 2¼d. per mile, amounts to 1s. 3d. per ton; whilst formerly the cost for conveyance by oxen amounted to 3s. 3d. per ton.

By A. EVRARD: Résumé de la Société des Ingenieurs Civils.

* From JAMES FORREST's "Abstracts of Papers in Foreign Transactions and Periodicals," for the Proceedings of the Institution of Civil Engineers.

ENGINEERING STRUCTURES.

FIRE-PROOF BUILDING IN VIENNA.—The following regulations are in force in Vienna in order to secure buildings in case of fire:—

1. When the position of a building is such as to make it desirable, as a precaution against fire, the ground floor must be vaulted. In the attic and in the first story, when the ground floor is not vaulted, the floors must be massive (as described), and a layer of dry mortar, sand, or other incombustible matter must separate the beams from the planking.

2. Stables and hay-lofts must have a fireproof ceiling.

3. Rooms for storing fuel must be, in general, located in the cellar, and built of masonry. When they are in sheds of but one story, they must, in addition, have a fireproof roof.

4. In every building fireproof stairways must communicate from the attic to the cellar, and with every dwelling by means of fireproof passages. (This implies that the vestibule should also be fireproof; and it is, in fact, invariably vaulted, and has a flooring of stone or *béton.*) In buildings of great extent there must be several such stairways, sufficient to enable all persons dwelling in them to pass readily out of doors.

5. When a stairway is lighted by means of a skylight, the frame of the latter must be constructed entirely of iron, and rest, on all sides, on masonry rising above the roof.

6. All stairways and passages connected with them must have a fireproof railing.

7. Woodwork must be removed from the interior surface of all flues by a thickness of at least six inches of masonry. The masonry of the chimneys must be plastered on the exterior, from the pavement of the attic to the highest point of the roof.

8. Each story shall be provided with at least one separate flue, passing without communication with any other to its exit at the roof. Where the beams of the floor rest upon the walls containing flues, an earthen pipe shall be inserted into the latter, having for its length at least the thickness of the whole floor, and for its thickness at least one inch. Every flue must have, at its commencement in the lower story, and also in the attic, a side opening, closed by two iron doors, closely shutting, and provided with a lock. Where several flues lie side by side, they shall be closed still further by an iron bar and padlock, extending over the openings of all. All woodwork in the vicinity of these doors must be covered with sheet-iron.

9. All roofs must be covered with tiles, slate, metal, or some other fireproof material. The woodwork of the roof must at no point be nearer than six inches to the pavement of the attic. Iron roof-frames must rest upon masonry alone; wooden cornices are forbidden.

10. The attic roof must be covered with tiles, cement, or other fireproof material. An iron door, hung in an iron frame, must communicate alone from the main stairway with the attic. At least once in every 90 feet of its length the attic must be sub-divided by a brick wall running across its width and rising 9 inches above the roof. (This is generally covered above with zinc.) The compartments ensuing shall communicate with each other only by means of iron doors hung in iron frames. No dwelling-rooms are permitted in the attics of buildings.

11. Every house shall be provided with a wall at least 6 inches thick, separating it from its neighbor—for the two houses thus ensues a wall of 12 inches.

The thickness of walls must be regulated by the weight they have to support and the material of which they are composed; also by the height of the stories and the construction of the floors and ceilings.

The following rules are to be observed:

(*a*) The principal outer walls, as well as all interior walls, at the point where they contain flues, must be at least 18 inches thick. The principal walls of the upper story must be at least 2 feet thick if the depth of the rooms is more than 20 feet. The main walls may have the same thickness in two successive stories. In buildings of three stories the main walls must, at the ground, be at least 2 feet thick; in buildings of four stories, at least 2 feet 6 inches thick. Those portions of the main wall which do not support floors can be made 18 inches thick for all stories.

(*b*) Where the ceilings are vaulted and rest on iron girders, in case the latter are not more than 20 feet long, the walls supporting them need only be 18 inches thick for all stories; where they are of greater length, the walls must be 2 feet thick.

(*c*) The foundation walls must, in all cases, be 6 inches thicker than those of the lower story.

(*d*) In light walls, the walls must be in all cases 18 inches thick where they support ceilings, or bound rooms used for dwelling purposes. In other cases, they need be only 12 inches thick.

(*e*) Walls supporting massive floorings of half or whole trees (as described) must be 2 feet thick, and the trees must rest for six inches at their ends upon the same.—*The Architect.*

ORDNANCE AND NAVAL.

THE PALLISER GUN EXPERIMENTS.—Recently Sir William Palliser, assisted by Captain Edward Palliser, made some important experiments with a view of ascertaining the ultimate strength of a gun lined with a coiled barrel, 7 in. in bore, and barely 3 in. thick. In point of fact the experiments were intended to contrast the action of coiled wrought-iron tubing in guns, under exceptionally heavy charges, with the steel-lined guns of the Woolwich pattern—the Thunderer 38-ton gun and the 38-ton gun lately burst at Woolwich being examples of the weapons against which Sir W. Palliser contrasts his system. There were present the attaches of the Russian, German, Austrian, and American Embassies.

The gun with which it was proposed to make the experiments was a weapon which has a history. It was a 10-in. cast-iron gun of 84 cwt. which served in the Crimea, and received a bruise on the side from a Russian shell and grape shot indentations at the muzzle. It was proved at Woolwich in 1839, served on the Hydra from 1847, and was employed throughout the siege of Sebastopol. Returned to Woolwich in 1856, it was sold to Sir William

Palliser in 1866, and by him converted into a 7-in. rifled gun of 95 cwt., after being variously used to try experiments with the steel lining. The steel lining having burst, Sir William Palliser has given the gun three tubes of coiled wrought iron—the first, that carrying the rifling, being ¾ in., the second the same, and the third 1½ in.—the whole encased in the cast-iron shell of the old gun. The gun was in a cell on the marshes, with her muzzle pointed into a mound of earth built round with boards. Provision had been made for the recoil by placing an incline behind the gun, up which her carriage would slide, and so utilize her weight for easing her down to the firing point, a spring buffer being placed at the top of the incline to receive what unexpended force might remain when the recoil had carried the weapon so far.

As the gun is one eighth of the weight of the 38 ton gun, it was proposed to commence the trials with the proportional double charge which burst the 38-ton gun at Woolwich. The gun was loaded with a rear charge of 13 lbs. 12 ozs of pebble powder and an 88 lb. "Palliser" shaped shot, and a front charge upon that of 10 lbs. 10 ozs. of powder and a 75-lb. shot—the whole double charge taking up about a third of the barrel's length. The charge was fired with a friction tube, and the only result was to send the timber-work flying. The bore was tested, but there was no perceptible giving of the metal. The second round consisted of 16 lbs. of powder and a 100-lb. shot for the rear charge, with 11-lbs. of powder and an 85-lb. shot for the front charge. There was more disturbance of the mound, but no great change in the bore of the gun, though the charge was much greater in proportion to that which burst the 38-ton gun. The third round consisted of 18 lbs. of powder in the rear charge and a 100 lb. shot, with 12 lbs. of powder and an 85 lb. shot for the front charge. The result of this was to throw the breech of the gun up on to the roof of the cell; but still the metal had sustained no fracture. The charges of powder for the next round were increased to 20 lbs. for the rear charge and 13 lbs. for the front, the projectiles being again 100 lbs. and 85 lbs. Sand bags were placed behind at the top of the incline to take the unspent recoil, and the gun was again found uninjured, with but little change in her bore. In the fifth round the charges of powder were increased to 22 lbs. and 14 lbs., and the charges together occupied rather more than half the tube. When the gun was fired the concussion was so great that the built-up boardings around were blown out, and when the gun was viewed in its dark cell by the light of a candle it was apparently uninjured. The bore could not be tested from the fact that the cell was blocked up by the fallen timbers.

There were no pressure guages placed inside the gun—a fact which was regretted by some members of the Government Experimental Committee present, the absence of the guages preventing accurate estimates being obtained as to the actual pressure of the charges; but the facts respecting the bearing qualities of wrought iron were plainly demonstrated.—*London Times.*

BOOK NOTICES.

PUBLICATIONS RECEIVED.

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS (advanced sheets).

Annual Report of the Minister of Railways and Canals in the Dominion of Canada, for the fiscal year ending June 30th, 1879.

Report of the Chief Engineer of Canals of the Dominion of Canada. By John Page, Esq., C.E.

Report of the State Engineer to the Legislature of California.

Plans for the Improvement of the Ohio River. Petition of Herman Haupt and of the Pittsburgh Chamber of Commerce. Congressional Document, No. 33, Mis.

Discussions on Inter-Oceanic Canal Projects. By Ashbel Welch and Julius W. Adams.

Special Report of New York State Survey on the Preservation of the Scenery of Niagara Falls. By James T. Gardner, Director.

The following papers of the Institution of Civil Engineers have been received through the politeness of Mr. James Forrest:

"Account of Two Drainages in Ireland." By John Hill, M.I.C.E.

"The River Thames." By John Baldry Redman, M.I.C.E.

"Experiments on the Resistance to Horizontal Stress of Timber Piling." By John Watt Sandeman, M.I.C.E.

"Abstracts of Papers in Foreign Transactions and Periodicals."

CAMP AND CABIN. Sketches of Life and Travel in the West. By ROSSITER W. RAYMOND, PH.D. New York: Fords, Howard & Hurlburt.

Nothing need be said here about the author of this delightful little book, nor of his remarkable versatility. Every one who enjoys accurate sketches of the scenery and people of the West, should have the book.

The skillful and graceful drawing of the human side of the rough western character is exceedingly enjoyable. And the delicate humor throughout the series of sketches fits the book remarkably for reading aloud to young and old together.

AN ELEMENTARY TREATISE ON ANALYTIC GEOMETRY, EMBRACING PLANE GEOMETRY, AND AN INTRODUCTION TO GEOMETRY OF THREE DIMENSIONS. By EDWARD A. BOWSER, Professor of Mathematics and Engineering in Rutgers College. New York: D. Van Nostrand. Price, $1.75.

Conciseness and clearness are the prominent characteristics of this new text book.

The author has made excellent use of the methods lately developed by leading writers, and has skillfully incorporated them in the treatise. At the same time there is no departure from the familiar order of subjects.

Among the conspicuous merits of the book may be mentioned the presentation of the symmetrical and normal forms of the equations of the right line and of the plane, the equations of the ellipsoid and of its tangent plane, and the formulas for the distances of a point from a line and from a plane. These are not usually found in American text books.

Another merit of the work which will be appreciated by instructors and students alike, is the selection of illustrative examples following each leading topic.

The author is a practical and successful instructor, and his book bears abundant evidence of it.

The mechanical execution of the work is excellent.

A Treatise on the Richards Steam Engine Indicator, with Directions for its Use. By Chas. T. Porter. Revised and adapted to American practice. F. W. Bacon, M.E. Third Edition. New York: D. Van Nostrand. Price, $1.00.

The former editions of this work have done excellent service as aids to the working engineers of this country. The present edition, like the former ones, is a compact hand-book of directions, rendered in plain and concise terms, and covering all the contingencies likely to arise to applying the Indicator to use.

The practical rules for the computations have been extended, and the use of the Pantograph and the Polar Planimeter are described in the supplement which appears in this edition.

The Indicator, but a few years since, was only in the hands of a few experts, and was regarded as a piece of mechanism whose successful use was beyond the capabilities of the common engineer. It would doubtless have occupied the same position to this time but for the editor of this little volume who is one of the most widely known experts in the land. With unusual talents for instructing, he prepared a set of instructions which has created a demand for the instrument from working engineers throughout the land.

Traverse Tables. Computed to four Places of Decimals for every Minute of Angle up to 100 of Distance. By Richard Lloyd Gurden. London: Charles Griffin & Company. For Sale by D. Van Nostrand. Price $12.00.

"Mr. Gurden is to be thanked for the extraordinary labor which he has bestowed on facilitating the work of the Surveyor. . . . An almost unexampled instance of professional and literary industry. . . . As to the value of the Tables themselves, one opening of the book, and a simple inspection and notation, without calculation, gives the information which, if sought by the usual method, requires the opening of the tables of logarithms in four different places, making two separate additions in order to get figures of second decimal places (those in the Tables being to four places), and making calculations involving the use of 48 more figures than are required to be written by the person who uses these Tables. . . . When the anxious and laborious work of one man affords the means of such a saving of toil for all those who avail themselves of his work, the patient and careful tabulator deserves the name of a benefactor of his profession, and a good servant of his fellows."—*Athenæum.*

Radical Mechanics of Animal Locomotion. By Wm. Pratt Wainwright. New York: Published for the author by D. Van Nostrand. Price, $1.50.

The practical bearing of this book relates to the "setting up" of soldiers, but, as the author suggests, may find many opportunities for application among civilians.

The writer offers through a knowledge of the mechanism of bony and muscular systems to afford a better than the usual expedients for overcoming "that fault in the body, whatever it may be, which, in nine hundred-and-ninety-nine men out of every thousand civilized nations, tends to hinder the man from marching in a straight line, from discharging his musket without destroying his aim, from cutting perpendicularly with the edge of his sabre, and which likewise hinders him from so following in his own frame the motions of the frame of his horse that the forces be absorbed in such manner as to give no recoil from the saddle."

Throughout the book the author adheres to the plan of giving specific directions to the learner, in regard to the position and action of each separate part.

MISCELLANEOUS.

The report of the Heberlein Brake Company, recently issued, states, that after an extended trial, the Heberlein brake, in its most recently improved form, is to be extensively adopted on the Bergisch Markisch Railway, which is one of the most extensive in Germany. It has been fitted on several trains on the Saarbrücken Railway, while on the Frankfort Railway and Lower Silesian Raiway twenty-two goods engines are about to be, or are being, fitted with the brake, the Breslau service of express trains on the latter railway having already been fitted with the brake. The report is accompanied with a statement of the result of trials which have led to its adoption in Germany and Russia.

The Society of Swiss Engineers and Architects have recently published, in a condensed form, a paper by M. Tóth, "On the Most Recent Advances in the Construction of Tunnels, especially in Germany." In his paper Mr. Tóth gave particulars relating to forty tunnels, but in the book he has occupied himself especially with ten, which, with their lengths, are as follows: The St. Gothard, 14,920 metres; Mont Cenis, 12,233; Hoosac, 7,622; Suttro, 6,205; Kaiser-Wilhelm Tunnel, Cochem, 4,205; Dettenberg, 1,800; Spitsberg, 1,747; Sonnstein, 1,429; Zimmeregg, 1,135; Teterchen, 1,075.